Imperial Institute
of
Agricultural Research, Pusa.

THE OHIO
JOURNAL OF SCIENCE

STUDIES ON ELEMENTAL SULFUR AS A SOIL INSECTICIDE.*

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INTRODUCTION.

Soil insects have always been a very serious problem to those engaged in agriculture. Numerous insects, chiefly in their larval form, almost universally infest both virgin and cultivated soils. The groups most commonly troublesome are grubs, wireworms, cutworms, rootmaggots, and rootaphids, or root lice, as they are commonly called. Certain species of a few other groups also cause, at times, considerable injury.

It would hardly seem necessary to emphasize the economic importance of each of these forms. The common white grub alone causes annually thousands of dollars of loss in agricultural products. Davis (*2†*) estimates that in 1912 this pest alone caused a loss of approximately $7,000,000 to corn, timothy, and potatoes, in the states of Iowa, Illinois, and Wisconsin. He also estimates the aggregate damage from this one insect throughout the entire country in the year 1912 to be upwards of $12,000,000. It is doubtful if adequate data are available to make anything like an exact evaluation of the loss in agricultural products sustained annually through soil-feeding insects. It would seem to the writer conservative to assert that throughout the entire country soil insects cause a loss of many millions of dollars annually.

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* Presented in the graduate school of the Ohio State University in 1924, prior to the author's appointment to a position in the Bureau of Entomology, United States Department of Agriculture, Washington, D. C., in partial fulfillment for the degree of doctor of philosophy.

† Figures (italics) in parentheses refer to the bibliography.

In recent years much work has been done along the line of insect control. Much more progress has been made in the control of air-feeding forms than of those that spend most of their feeding period in the soil. At the present time most insecticides are very limited in their use against soil-feeding insects, though some of them are very effective against forms which feed on leaves. This is probably because the conditions under which insecticides must be used in combating soil insects are so different from those under which they are applied in the control of forms that feed upon the aerial portions of plants that an extensive or general use of most known insecticides is impracticable, if not almost impossible. This is particularly true in the case of stomach and contact poisons. Volatile or gaseous insecticides are also limited in their use as soil insecticides but it would seem to the writer that they have more promise as general soil insecticides than either stomach or contact poisons.

The ideal soil insecticide would be some substance which, when applied to the soil, would exert a toxicity fatal to the insect fauna which inhabit it, and at the same time would not produce any permanently detrimental effect on cultivated crops. It is not probable that any such a panacea will soon be discovered. However, if some substance of use in agriculture could be found effective as an insecticide, even to a limited extent, or if such a substance was found capable of being manipulated in such a manner as to give it insecticidal value, the dual value of such a substance would aid materially in promoting its use as a soil insecticide. It was with this idea in mind that the writer undertook the study of the insecticidal properties of elemental sulfur.

Elemental sulfur has been found to have value as a fertilizer, chiefly in some of the western states. It has been found effective in the control of potato scab, and useful in producing a reaction favorable to crop growth in alkali soils. There are also some unauthenticated rumors as to its value in controling insects in places where it was used to control potato scab.

Investigations as to the chemical reactions of sulfur, which will be taken up in detail later in this paper, show that sulfur in the soil is converted to sulfates. It is known that during this process sulfurous and sulfuric acids are formed. In the early stages of this process, at least theoretically, SO_2 is produced, and under restricted conditions (the breaking down of

organic matter, especially that rich in protein) H_2S may be produced. If some of these transitional products, or some other products resulting from the reaction of sulfur with certain soil elements, should be found toxic to soil insects to an extent sufficient to make them of insecticidal importance, the fertilizer and other previously mentioned used of sulfur in the soil in many cases might aid in making its use as a soil insecticide more practical.

The object of this research, and the purpose of the Texas Gulf Sulfur Company and the National Research Council in initiation and supporting it, was to ascertain the possibilities and the limitations of elemental sulfur as a soil insecticide. In this work, therefore, the investigator was limited to the use of elemental forms of sulfur. Inoculated sulfur and flour of sulfur were the two forms uses in most of the experiments of this research. A more complete statement concerning them is given later in this paper.

The term "Soil Insect" is used in this paper only in referring to those insects the adult or larva of which spends a considerable portion of its feeding period in the soil.

In the selection of insects for use in this research it was thought advisable to experiment on forms representing as widely differing types as were available, and, at the same time, forms which were of great economic importance. With this in mind the writer chose ants (*Formica fusca subsericea*), root maggots (*Hylemyia fusciceps, and H. Brassicea*), the common white grub (*Phyllophaga Sp.*), wireworms, rootaphids, and cutworms.

In some preliminary work the rootaphis was found not to lend itself very readily to experimentation, and consequently very little work was done with it. A brief discussion and reference to some work done by the author in conjunction with Dr. C. R. Cutright, of the Ohio Experiment Station, Wooster, Ohio, is given in the latter part of this paper.

Two general types of experiments were carried on in this research: (a) insectary tests to determine the insecticidal possibilities and limitations of elemental sulfur and some of its transitional products, such as SO_2, H_2SO_3, H_2SO_4, and H_2S, which, according to Joffe (4), are produced in the soil through the transformation of sulfur to sulfates; and (b) field-plot experiments, in which observations were made as to the degree of injury done by insects to crops grown on plots the soils of which had been treated with elemental sulfur. Observations

were also made during these experiments on the effect of sulfur treatments upon the soil and the vegetation supported by it.

THE TRANSFORMATION OF SULFUR IN THE SOIL.

The transformation of sulfur in the soil may take place either by oxidation or by reduction. The end product of either of the processes is a sulfate, which is the form in which sulfur is utilized by plants. It is evident then that through its transformation into sulfates, sulfur is made available to plants.

Sulfur transformation in the soil occurs chiefly through oxidation. However, under anaerobic conditions such as are found in the organic muck at the bottom of lakes, or in any place where vegetative or organic decay takes place, largely in the absence of air, sulfur may be reduced and H_2S be liberated. This in turn is oxidized, and sulfates are ultimately formed as in the case of sulfur oxidation.

From Joffe's review of the literature (4), which deals with the transformation and uses of elemental sulfur, there seems to have been considerable controversy between some of the early workers as to whether sulfur transformation was a chemical or a biological process. Recent work in which special sulfur-oxidizing bacteria have been isolated has established quite conclusively that this transformation is, at least, largely biological.

A number of organisms capable of oxidizing and some capable of reducing, sulfur have been isolated. The most important of these sulfur-transforming organisms are two species which oxidize sulfur:—*Thiobaccillus thioparus*, Nathanson (7); and *Thiobaccillus thiooxidans*, Lipman, Waksman, and Joffe (8). According to Joffe (4) it is doubtful if T. thioparus is capable of oxidizing elemental sulfur, although Jacobsen (3) reports that it is. Joffe points out that these two organisms have very fundamental physiological differences, the latter being very active in alkaline, and the former in acid, mediums. .

The oxidation of elemental sulfur, whether chemical or biological or both, results in the production of sulfuric acid which in turn reacts with various soil constituents to form sulfates. Soils that are highly buffered may not become acid for some time. In many soils, however, especially those that have been farmed for a considerable time, the oxidation of sulfur changes the reaction rapidly so that the soil soon becomes strongly acid.

Reactions for sulfur oxidation in the soil

Joffe (*4, p. 48*) gives the following reaction for the oxidation of sulfur in sulfur-float mixtures:

$$2S + 3O + 2H_2O = 2H_2SO_4$$
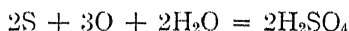
This reaction is probably identical with that which occurs in a soil which has been treated with elemental sulfur. Let us now follow step by step what probably occurs in this reaction. If we begin with elemental sulfur we may assume that, at least momentarily, SO_2 is produced as the first product of sulfur oxidation:

$$S + O_2 = SO_2$$
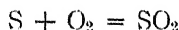
When SO_2 comes in contact with the moisture in the soil it almost immediately unites with a molecule of water and forms sulfurous acid:

$$SO_2 + H_2O = H_2SO_3$$

This in turn undergoes oxidation and sulfuric acid is produced:

$$6H_2SO_3 + 3O_2 = 6H_2SO_4$$
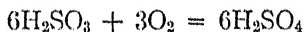
From this analysis of the reactions taking place in the oxidation of sulfur it would appear that when the oxidation of sulfur occurs in a soil SO_2, H_2SO_3, and H_2SO_4, all of which might be toxic to soil insects, are produced. Under special conditions, as previously noted, H_2S might also be produced in the course of the transformation of sulfur. The experiments described in the following pages were undertaken to determine the toxicity of these transitional products of sulfur to some forms of a few soil insects.

GENERAL EXPERIMENTAL PROCEDURE.

Types of Experiments.

In the carrying out of this research both insectary and field methods were used. In the insectary tests were made to determine the toxicity of the previously mentioned products of oxidation and reduction of sulfur to soil insects, as well as any direct effect that elemental sulfur itself might have upon them. In the field turnips, radishes, and potatoes were grown on soils treated with sulfur and the degree of infestation of crops by rootmaggots and white grubs noted. The detailed results of these experiments will be given further on in this paper.

Kinds of Sulfur Used.

As previously stated one of the specific conditions of the fellowship fostering this research was that it should be confined to the use of elemental sulfur, thus excluding the use of any of the commercially prepared compounds of sulfur except where they might be used in conjunction with some elemental form of it, as, for example, in experiments where sulfur was tested as a carrier of materials of known insecticidal value, such as carbon bisulfide or nicotine sulfate.

In the various experiments of this research only flour of sulfur and inoculated sulfur were used. These were chosen because they are the principal forms of elemental sulfur used in work relating to soil fertility and to the control of potato scab. Both of these products were furnished by the Texas Gulf Sulfur Company. Flour of sulfur is simply finely ground brimstone, and inoculated sulfur is flour of sulfur which has been inoculated with a species of bacteria known to be especially active in the oxidation of sulfur. A few preliminary tests were made in which the activity of flour of sulfur and flowers of sulfur were compared, and since no difference in reactivity could be detected, the latter was not used in any of the tests recorded in the following pages.

The Determination of Soil Acidity.

Since soil acidity is one of the results of the oxidation of sulfur in the soil, and because this acidity might have some effect upon the insect fauna of the soil, it was necessary to determine the acidity of each of the soils in the following experiments and to note it in connection with insecticidal and other observations.

Although various acids may be equal quantitatively, they usually do not dissociate equally; in other words they do not possess equal intensities. It is therefore evident, so far as biological effect is concerned, that a method of determining acidity, which is a measure of the intensity, without regard to which or how many acids are present, is the most suitable. For this reason the method of determining the hydrogen-ion concentration, which Clark (1) has termed the method of measuring the intensity of an acid, was used in preference to measurements involving titration with standard alkali solutions, which are really only quantitative determinations.

The Determination of Hydrogen-ion Concentrations.

There are two general methods by which hydrogen-ion determinations are commonly made; first, the electrometric method, which is really the basis for all hydrogen-ion measurements, and when carefully and properly made gives much more refined results than any other method; second, the colorimetric method, (5), by means of which measurements can be made directly to within 0.2 of a pH, and by interpolation values as small as 0.1 pH can readily be made.

Although the electrometric method is much the more refined, and even makes possible the making of measurements in cases where physical and chemical factors would interfere with the accuracy of colorimetric tests, the technique necessary for the proper manipulation of an electrometric apparatus is greater, while the convenience and rapidity of making the tests is less, than those of the colorimetric method. The cost of a reliable and convenient electrometric apparatus is also greater than that of a colorimetric one. For these reasons the colorimetric method was chosen and used in this research in making the determination of pH values.

Apparatus For Colorimetric Hydrogen-ion Determinations.

For the determination of hydrogen-ion concentrations the following are necessary: indicators (Clark 1-, p. 80); standard buffer solutions from which a series of solutions, ranging in pH value from 1.2 to 9.8, can be prepared; about a dozen test tubes of approximately 20 c. c. capacity and of uniform diameter, so that the same depth of liquid will be concerned in all comparisons; and some wide-mouthed glass bottles in which to prepare extracts of the substances the hydrogen-ion concentrations of which are to be determined. The buffer solutions recommended by Clark (1) are very satisfactory: in this research, however, those recommended by MacIlvaine (6) were found equally satisfactory.

Samples For Use in Hydrogen-ion Determinations.

For each hydrogen-ion determination from 2 to 10 grams of soil were taken, placed in a clean glass bottle, and set aside until a number of samples had been collected. Generally the determinations were made within from 24 to 48 hours after the samples had been taken.

In the insectary experiments, where the sulfur and other constituents were more or less intimately mixed with the soil, only one sample was taken from each container. This sample was taken at the time when the soil had been removed from the various containers, so that observations could be made as to the condition of the insect. Each of these soils was thoroughly mixed before the sample was taken and then the soil and insect were again placed in the container.

In the field experiments determinations of hydrogen-ion concentration were made both for the surface (0 to 2 inches deep) and for the sub-surface (2 to 4 inches deep). In procuring samples for these determiantions samplings were made at three or four representative places on each plot. After all the samples which were to be taken on a particular date had been procured the hydrogen-ion concentrations of all were determined in accordance with the details given below.

Procedure of Making Hydrogen-ion Determinations.

During most of the year 1922-23, through the courtesy of the Department of Physical Chemistry of Ohio State University, the determination of hydrogen-ion concentrations were made in the above laboratory by means of indicators and buffer solutions which they had prepared in accordance with the method of Clark (*1*). At beginning of the year 1923-24, on account of the inconvenience of this procedure and the time required to transport all the solutions to and from this laboratory, dyes were procured and a set of indicators prepared according to Clark (*1*, p. 80, 81). The buffer solutions used with this set of dyes were prepared according to MacIlvaine (*6*) instead of according to Clark. This change was made because by means of these buffers a satisfactory color range could be prepared with but two solutions, small portions of the two being united in such a manner as to procure a range of pH values from 2.0 to 8.0.

In the experiments described in the following pages it was not found necessary to make measurements of pH values above the upper limit of this range. Where it was desirable to make measurements of acidity represented by pH values below the lower limit of this range, the buffer solutions of the Department of Physical Chemistry of Ohio State University were used.

Manipulations in the H-ion Tests.

In making the various determinations of pH value each sample of soil was thoroughly mixed and the coarse sand and pebbles removed by means of a 12 mesh wire screen; 2 grams of this soil were then placed in a clean bottle of approximately 100 c. c. capacity and 100 c. c. of distilled water was then added; the contents of the bottle were vigorously shaken and then set aside until the solution became clear enough to make color comparisons with standard buffer solutions colored by the same indicator. In from 2 to 4 hours the solutions were usually clear enough to be fairly workable. It was found by preliminary tests that leaving a solution for this length of time did not usually cause any significant change in its pH value.

The approximate pH value of the solution being tested was first determined by placing about 2 c. c. of the clear solution in a test tube and adding a drop of the indicator within the range of which it was thought the pH value of the solution in question might fall. A glance at this test enables one to see if the proper indicator has been used and, if not, whether the solution is more or less acid than can be determined by it. If the first indicator tried is not the proper one, other indicators, selected in accordance to the indications of this test, are used with similar portions of the unknown solution, until one is found with which this particular determination can be made. Next, 10 c. c. of the unknown are pipetted into a test tube and 5 drops of the indicator then added. After shaking, so as to distribute the color uniformly throughout the solution, color comparisons were made with tubes containing the same quality of buffer solution which had been colored with the same indicator. The pH value could then be read from the standard buffer tube whose color most nearly matched that of the unknown solution.

Even after 4 hours or longer, the cloudiness of the solutions made the determinations difficult when compared in the usual manner with the colored standard buffer solutions.   A simple method of holding the tubes, suggested by Dr. Thomas G. Phillips, of the Department of Agricultural Chemistry of Ohio State University, and illustrated in the accompanying diagram, helped very materially in getting more nearly the correct readings.   In the diagram 1 is a water blank, 2 a tube of the unknown solution to which no indicator has been added, 3 is precisely like 2 except that it contains five drops of the appropriate indicator, and 4 is a tube of the buffer solution to which five drops of the indicator has been added.   By arranging these tubes as shown in the diagram, holding them up to the light, and placing different standard buffer tubes in position 4 until one is found which matches the color of the unknown to which the indicator had been added, it was a fairly easy matter to determine the pH value of the somewhat turbid solutions.
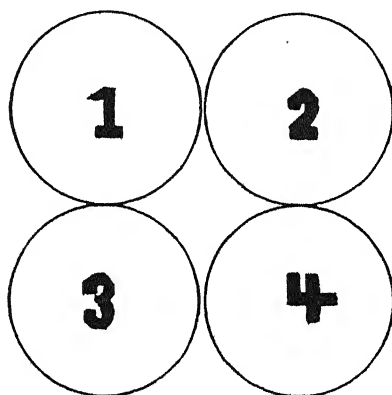
In all the hydrogen-ion tests made in the spring and summer of 1924, which include a large portion of the experiments the data of which are given in this dissertation, the solutions were centrifuged free of sediment before the hydrogen-ion determinations were made.   This procedure was much more satisfactory, and greatly facilitated the determinations.

Feeding Insects in Insectary Experiments.

Where the soil acidity was great, the feeding of insects in insectary experiments was rather difficult on account of the effect which this acidity had upon the green vegetation, roots, seeds, etc., that were used as food.

Where the soil was not too acid for seed germination and plant growth, corn seedlings were used as food.   In the more acid soils pieces of potatoes, fresh grass, grass roots, etc., were used instead of corn.   These materials were placed in the soils of the various containers and renewed from time to time in the course of each experiment, so that a supply of fairly fresh food was always available.   In the insectary experiments in which direct treatments of sulfur were made, the same

general method of feeding was followed, and the same food materials were used.

In all experiments upon ants granulated sugar was used as food. A small tin or paper tray containing a small quantity of sugar was placed upon the surface of the soil of each nest. The sugar was replenished from time to time, so that a constant supply of food was always available.

Moisture Content of Soils Used in Insectary Experiments.

All the soils used in the insectary experiments were first reduced to an air-dry condition. Stocks of the soils used in making up the various tests were kept in the insectary in that condition, so that tests could be prepared with a definite, known content of water, thus making it possible to keep the moisture content of each soil approximately constant throughout the course of each series of experiments.

The amount of moisture which it was considered desirable to maintain throughout most of the insectary tests was that which would be about the optimum for plant growth. This was determined by a method, recommended by the Department of Soils of Ohio State University, which consists in making a soil sufficiently moist that when grasped in the hand it would cohere just enough to form a slight ball. The quantity of water necessary to make of this consistency the soil, from which the stock soils used in the various insectary experiments were prepared, was calculated as 0.4 c. c. per gram of air-dry soil. This quantity of water was added to the stock soil in the preparation of each series of experiments except those in which tests for the production of H_2S were made.

The moisture content of the soils of each series of experiments was kept as constant as possible throughout the course of each experiment, by frequent weighings and the addition of water when needed. This eliminated as far as possible the effect that a variation in moisture content might have upon the insects.

In the experiments where toxicity of H_2SO_2 and H_3SO_4 to insects was being tested, the quantity of water required daily was omitted for several days before the acids were applied, or until about 100 c. c. of water was required to make the soil of each container up to its required moisture content. This made it possible to add the acid with the water and in this manner to obtain better and more immediate distribution of the acid throughout the soil, and at the same time to avoid adding more liquid than would just make each soil up to the desired weight.

The Preparation of Acid Soils For Use in Insectary Experiments.

Since sulfuric acid is known to be the chief acid which is produced in the soil through the oxidation of sulfur, in order to obtain more quickly soils with the desired degree of acidity, pots of field soils, with pH values of about 6.8 to 7.2, were treated with varying quantities of sulfuric acid until, when the reaction had reached an equilibrium, 6 soils had been obtained with pH values of approximately 2.0, 2.3, 3.4, 4.7, 5.1, and 7.0, respectively. These soils were then air dried and a supply of each kept in this condition in the insectary as stocks from which to prepare the various series of acid soils used in the toxicity experiments noted in the following pages.

Temperature Regulation in the Insectary Experiments.

No device for controling the temperature of the soils in the various experiments was available, and so the pots and cages used in each experiment were simply placed in as nearly identical conditions of temperature as were possible. By this procedure it was thought that the temperature of the various soils of each series would at least be comparable.

TOXICITY TO ANTS OF SOME PRODUCTS OF SULFUR OXIDATION AND REDUCTION.

Since H_2SO_4 is known to be produced in the soil through the oxidation of sulfur and since it is probable that SO_2, H_2SO_3, and possibly H_2S are produced, under certain conditions, in the course of this reaction, it was thought advisable to ascertain the degree of toxicity of each of these products to some form of an insect which lived in the soil.

Ants (*Formica fusca subsericea*) seemed to thrive fairly well under cage conditions, and for that reason were chosen as the insect to be used in these tests. Cages with tightly fitted lids of screen, Plate 1, B, were used to confine the ants so that definite observations and counts could be made.

Tests were simultaneously made with the first three of the substances named, and the details and results are presented in Table I. Equal quantities of air-dry soil were placed in the several containers and then made up to and maintained at a uniform moisture content. The same number of worker ants were placed in each cage, and the various substances applied after the ants had established nests.

The reaction of the soil was recorded in terms of pH value which was determined from a sample taken when the soil was removed to make counts of the number of living ants and to thoroughly mix the soil in order that it might have a uniform reaction throughout. Further details are given in the discussion of the treatment by each specific substance.

Sulfur Dioxide.

Theoretically, SO_2 is the first product formed in the oxidation of sulfur in the soil. Though it almost immediately unites with the H_2O of the soil and forms sulfurous acid, it was thought that possibly during this reaction SO_2 might be of some insecticidal importance. For this reason an experiment

was planned (cage 20, Table I) to determine if it is possible to introduce enough SO_2 into a soil to be of value insecticidally.

By means of hard rubber and glass tubing, SO_2 gas was bubbled into the soil of the cage from a cylinder of compressed gas and it was distributed throughout the soil by means of perforations in that portion of the rubber tubing which was in the soil. This portion of the tube was 6 or 7 inches long and was coiled at the bottom against one side of the battery jar. The tube was placed in this manner, rather than entirely encircling the jar, in order that a better idea might be obtained

TABLE I.

DATA RELATING TO EXPERIMENTS ON THE TOXICITY OF SO_2, H_2SO_3, AND H_2SO_4 TO ANTS (*Formica fusca subsericea*).

Cage No.	Number of ants intro- duced May 5th	Soil (b) treatments May 7th		Living Ants May 15	Ave. pH Value of	Observations May 23rd
		Material	Quantity c. c.			
18	20	H_2SO_4	40	0	2.55	....
19	24	H_2SO_4	25	8	4.8	Very little activity.
20	20	SO_2	(a)	9	7.1	Ants active.
21	20	No treat- ment	....	18	· 7.4	Ants very active.
22	21	H_2SO_3	40	8	7.3	Some activity.

(a) This gas was bubbled into the soil for several hours from a cylinder of the compressed gas at the rate of 40 bubbles per minute.

(b) The soil of each nest consisted of 800 grams of air-dry soil and 400 c. c. of tap water.

as to the penetrating ability of the gas. After it had been placed in position the ants were put into the cage and allowed to establish their nest before introducing the gas.

In order to obtain some idea as to how rapidly the gas was being forced into the soil the end of the tube connecting the cylinder with the distributing tube was held under water and the number of bubbles per minute counted, before it was connected with the tube in the cage. At the beginning of the experiment, 4 P. M., the jet was regulated at 40 bubbles per minute; at 7 P. M. the gas was found to be running at the rate of only 4 bubbles per minute. It was again adjusted at 40 per minute and left undisturbed until morning, when it was found that the pressure had decreased enough that the bubbling had ceased though the tank still had gas in it.

After 8 days nine of the ants were still living. In this time 11 dead ants had been removed from the surface of the soil, most of the having been found directly over the perforated part of the discharge tube.

It is evident that in this experiment SO_2 did not give a very satisfactory insecticidal effect, even when bubbled into the soil at a more rapid rate than one would expect the gas to be produced in a soil through the oxidation of sulfur. It is also evident, since most of the dead ants were found directly over the place where the gas was discharged into the soil, and the living ants were carrying on their activities toward the opposite side of the cage, that SO_2 does not penetrate far into a soil. This lack of penetration is more than likely due to the fact that it unites so readily with the H_2O of the soil, thereby forming sulfurous acid.

Experiments cited later in this paper, in which elemental sulfur was applied to the soil of field plots, indicate that the soil from which the soil used in this test was taken was very highly buffered, or at least, the application of as much as 4,000 pounds of sulfur per acre made only a slight change in its acidity.

While this test shows that SO_2, even when applied in large quantities, is not efficient as a soil insecticide, it also shows that this gas if present in the soil in a sufficient quantity, is considerably toxic to the ant, *Formica fusca subsericea*.

Sulfurous and Sulfuric Acids.

The application of sulfurous acid was made by pouring it into the soil, after the ants had established nests in soils prepared as indicated in Note b, Table I. In order to obtain better distribution of the acid throughout the soil, the addition of the quantity of water necessary to keep the soil at a constant weight was omitted until the deficit amounted to about 100 c. c. The quantity of acid indicated in Table I was then added to just enough water to make the number of c. c. of liquid added just equal to the deficit in moisture content.

With this method of procedure a better distribution of the acid throughout the soil was obtained and at the same time the liquid content of the soil was not increased beyond that previously determined as that to be maintained throughout the test. The applications of sulfuric acid were made in the same manner as that used in case of sufurous acid. In these tests 50 per cent commerical acid was used.

The soils, both in the sulfuric and sulfurous acid tests as well as in the check, were removed from time to time in the course of the experiments to permit definite counts of the number of living ants. At these times the soil of each was intimately mixed, so that its acidity would be more uniform throughout.

From Table I it will be seen that sulfurous acid was somewhat toxic to ants, even though the acidity of the soil was ultimately but slightly increased. The toxicity in this case might have been due to the fact. that when the acid solution was poured upon the soil in the cage it run down the burrows, and probably came directly in contact with some of the ants. This, at least, was true in some of the nests which were treated with sulfuric acid. It is also probable that the soil along some of the burrows was much more acid than that farther from them, since the quantity of solution added was found insufficient to wet all the soil in the nest.

The results set forth in Table I show that sulfuric acid is somewhat toxic to these ants. Some ants, however, lived for several days in one of the soils treated with this acid. This was also true in some preliminary experiments in which the soil of ant nests was treated with sulfuric acid. In these preliminary experiments wooden cages with glass sides were used. The ants were induced, by keeping the sides of the cages covered with cardboard, to make their burrows out against the sides of the cage, thus enabling observations to be made upon them while in the burrows.

The treatment of the soil in this type of cage was much like that of cages 18 and 19 (Table I), except that the soil was not removed and mixed at the time the observations were made. In these preliminary experiments some ants lived and continued active for nearly 50 days and although no queen was present and no eggs were seen at the time the soil and ants were brought in from the field, several larvæ were reared to maturity and emerged as queens while these experiments were in progress.

The hydrogen-ion concentration of the soils in the cages of these preliminary experiments varied from 1.9 to 5.6 pH in the nine determinations that were made. This wide variation was undoubtedly due to the imperfect distribution of the acid throughout the soil. The average pH value was 3.0 for the soil of one cage, and 3.5 for the other. In these cages the samples used in making determinations of the pH value were

taken by means of a small auger, in such a way that a composite sample of the soils from top to bottom of the cage was obtained.

Although the results of this set of tests are not entirely conclusive, they indicate that sulfuric and sulfurous acids are toxic to ants under the conditions in which they are applied in these experiments. They also show that ants are able to endure very high degrees of soil acidity.

Hydrogen Sulfide.

In order to determine whether hydrogen sulfide was toxic to ants, (*Formica fusca subsericea*), H_2S gas was generated from ferrous sulfate in a hydrogen generator and bubbled into the soil of an ant nest. The same cage and the same type of apparatus was employed as that used in testing the toxicity of SO_2. Since it was impossible to control the rate at which the gas was generated, no estimate could be made as to the rapidity with which it entered the soil.

The generator was connected with the cage and left running for a few minutes, or until a very decided odor of H_2S was detected in the soil of the cage. By this method H_2S was found to be decidedly toxic to these ants, for it was necessary to bubble it through the soil for only a few minutes to kill all the ants in the nest. It is not probable, however, that this gas is ever produced in the soil in any such a quantity as was used in this test.

Since this gas is produced in the soil through bacterial decomposition of organic matter, it was decided to attempt its production from composts of manure, soil, and sulfur. Fresh horse manure, which had been piled out of doors for about two months, but had not been permitted to burn out, was mixed with varying proportions of soil and elemental sulfur, as shown in Table II; each mixture was placed in a battery jar, and a quantity of water, noted in the table, added. In most cases the water was sufficient to produce a water-logged condition in the mixture.

This experiment was begun May 6 and terminated July 20. The presence of H_2S was detected by means of small strips of paper moistened with lead acetate solution and placed in Petri dishes resting on the surface of the composts. The papers in all the jars except those numbered 2 and 6 were blackened slightly, showing the presence of H_2S. On June 14 a fresh

lead-acetate paper was placed in each Petri dish, and the time required for each to begin to blacken was noted.

By this series of tests it was shown that H_2S is produced in composts of manure, soil, and sulfur, and that a high organic content, or a high moisture content, is necessary to its production.

In order to determine whether the quantities of this gas produced in these composts were sufficient to be of insecticidal value, 9 to 10 ants were placed in each of the jars numbered 1, 2, and 5, and observations were made as to the length of time

·TABLE II.

DATA RELATING TO THE PRODUCTION OF H_2S, IN COMPOSTS OF
MANURE, SOIL, AND SULFUR.

Jar No.	Quantity of Manure	Quantity of Sulfur	Quantity of Air-Dry Soil	Quantity of Water Added	Days Until Lead-Acetate Paper Blackened After Exposure on—	
	Grams	Grams	Grams	c. c.	May 6	June 14
1	908	15	0	0	11	4
2	36	3	1211	605	(a)	(a)
3	908	15	0	454	19	8
4	36	3	1211	908	(a)	36
5	454	100	454	454	27	10
6	908 (b)	0	0	0	(a) (c)	(a)

(a) Where no figure for days is given there was no change in color.

(b) In jar No. 6 manure alone, in the same condition in which it was when brought into the insectary, was used as a check.

(c) Exposed May 25. No lead-acetate paper previously in the jar.

the ants lived. The nature of the composts made counts of the numbers of living ants impossible. However, after 4 days living ants were seen in all of the jars, from which the conclusion was reached that the quantity of H_2S evolved was not sufficient to be of insecticidal value.

TOLERANCE OF INSECTS TO ACID SOIL.

In testing the tolerance of insects to acid soil, stock soils which had been made acid by the use of sulfuric acid solutions were used. Various series of pot and cage soils with pH values ranging from about 1.9 to about 6.4 were prepared and used in these tests. Insects were placed in or upon the soils of the

various containers, and observations were made from time to time as to the presence and condition of the insects. In making these observations the soil of each pot was removed, and before being returned to the container it was thoroughly mixed and a sample taken for the determination of the hydrogen-ion concentration. This mixing helped to create a more uniform reaction throughout the soil of each cage, and thus necessitated the taking of but one sample from each soil for the determination of its pH value.

By this method of making observations it was possible to determine just how long the insect lived in each of the soils, and by comparing the longevity of the various individuals to get an idea as to whether acid soil is toxic to insects, and how

TABLE III.

DATA RELATING TO EXPERIMENTS ON THE LONGEVITY OF ANTS IN ACID SOIL.

Cage No.	Number of Ants Introduced	pH Value	Number of Living Ants Found in Each Cage on the Following Dates					
	June 18	June 19	June 20	June 23	June 27	July 1	July 7
1	12	1.9	0	....	....	....	....
2	12	3.3	9	9	9	9	8
3	12	5.2	10	9	8	7	7
4	12	6.4	10	10	10	10	9

acid a soil they can endure. Ants (*Formica fusca subsericea*) and the common white grub (Phyllophaga Sp.) were the chief insects used in these experiments. A few wireworms and some cutworms were also placed in some of the soils in the course of the white-grub experiments.

Ants.

In this series of experiments 12 ants (*Formica fusca subsericea*) were, on June 18, placed in each of four cages. The soils of three of these cages had been treated on May 18 with solutions of sulfuric acid and on June 19, after having been thoroughly mixed, they gave the pH values given in Table III.

As shown in the table, all the ants in the most acid soil were dead within 24 hours after being put into the cage. In the other cages the longevity of the ants was nearly uniform.

In order to verify the result in cage No. 1, another lot consisting of 6 ants was placed upon the soil of this cage at 10 A. M., June 20; at 5 P. M. of the same day 3 of them were dead, and by the next morning all 6 were dead.

From both this and preceding experiments in which ant nests were treated with sulfuric acid, it is evident that the species of ant used can tolerate a high degree of acidity. Although soils with as great an acidity as that in cage No. 1, are very toxic to ants, it is evident from the record for cage No. 2, that ants can live for a considerable time in soils which are too acid for the growth of much vegetation.

Just how the acidity of the soil in cage No. 1 caused the death of the ants was not determined. Titrometric methods of determining the acidity of the soil of this cage showed it to be slightly greater than that represented by the pH value. It is possible that insufficient time for the reaction to have reached an equilibrium had elasped since this particular stock soil had received its last application of sulfuric acid, and that acid soil in this condition exerts a greater effect upon ants than that of a soil whose acidity is entirely measureable in terms of pH value. It may also be that some volatile substance was produced, or that death was due to the dehydrating effect of the sulfuric acid upon the ants.

In a test in which ants were placed in a screen tray just above the surface of the soil of this cage, thus preventing them from coming in contact with the soil, it was found that the killing was almost as rapid as when direct contact was permitted. It was found that the higher above the soil the tray was placed the slower was the killing. With the tray 3 inches above the soil some of the ants lived 2 days.

From the results of these experiments, it would seem that soil acidity would not be very useful as a means of controling or extermination such insects because in order to get an immediate or rapid killing the acidity of a soil must be increased to a point much above that which vegetable life can endure. It is, also, evident that the acidity must be uniform throughout all parts of the ant nest to effect their extermination. This was fairly well shown in the previously mentioned preliminary experiments in which the toxicity of sulfuric acid to this species of ant was being tested in cages from which the soil could not conveniently be removed and consequently the acidity was not uniform throughout it.

White Grubs.

In the series of experiments the data of which are given in Table IV, wooden cages with glass sides were used as soil containers. These cages did not prove very satisfactory and were used only for this one series of tests. In all the subsequent experiments, in which the toxicity of acid soil to white grubs was tested, flower pots three inches in diameter or jelly glasses were used as soil containers. The vents in the bottom of the pots were tightly corked, to prevent the loss of water and, especially in the case of wireworms, the escape of the insect larva. Both the pots and the tumblers were covered with small plates of glass to prevent excessive loss of moisture through evaporation. The data of these experiments are given in Table V.

The soils of the several pots of each of these experiments were prepared from the stocks of acid soils the preparation of which has been described earlier in this paper. Each series, which consisted of six or eight soils, was prepared in such a manner that their pH values formed a gradually increasing series of hydrogen-ion concentrations ranging from almost neutral to very acid as shown by the pH values in the table.

In preparing these experiments equal quantities of air-dry stocks of acid soils were placed in the various containers and made up to a moisture content which, as previously noted, was about the optimum for plant growth. By frequent weighings, and additions of water when necessary, the moisture content of each soil was kept as constant, throughout the course of the series of tests to which it belonged, as the conditions would permit.

In the series of soils the data of which are presented in Table IV, 4 or 5 grubs were placed in each container. This plan, however, did not prove satisfactory because observations could not be made upon the individual grubs and, besides, the grubs were liable to pinch each other; in some cases it was thought that the death of the grub was due to this cause rather than to any other. In most or all of the experiments the data of which are given in Table V, but one grub was placed in each container.

Observations were made, at frequent intervals, as to the presence and condition of the grub. Both soil and grub were carefully removed from the container, and put back into the

container after the observations had been made.   At the same
time a fresh supply of food was provided, if necessary.   Each
soil was thoroughly mixed before being returned to the container.

In the first series of tests, although the average longevity
of the grubs in the more acid soils (those treated with sulfuric

TABLE IV.

DATA RELATING TO EXPERIMENTS ON THE TOLERANCE OF WHITE GRUBS
FOR ACID SOILS.

Cage No.	Number of Grubs	Daily Water Require- ment c. c.	Average pH Value	Days of Tolerance	Average Days of Tolerance
19	4	3.48	2.38	7 17 14 41	17.25
22	4	2.50	2.55	7 7 7 14	8.8
20	4	3.11	2.63	3 7 13 15	9.5
23	5	2.7	2.75	7 24 24 41 41	27.4
24	5	7.2	5.9	13 41 41 41 41	35.4
21	4	7.6	6.1	13 24 41 41	29.8

acid) was less than that of the grubs in the checks, some of the
grubs in these soils lived as long as any of those in the check
soils.   The data relating to this series of experiments are pre-
sented in Table IV.   Cages numbered 21 and 24 contained
soils which had been taken from the field in which most of the
grubs used in this research were collected.

The data in Table IV and V show considerable variation in
the length of time the grubs lived in the various soils.   How-

ever, only when the soil acidity was greater than that expressed by a pH value of 2.7 did there seem to be a decided toxicity of such soils to the white grub.

These variations in longevity can perhaps be partially explained through the fact that, since there was no means by which the temperature of the soil in the various containers could be controled, the temperature in some of the soils, at times, ran very high. This undoubtedly had a considerable effect on the grubs. In fact, several grubs were found dead during and just

TABLE V.

DATA RELATING TO EXPERIMENTS ON THE TOLERANCE OF WHITE GRUBS FOR ACID SOILS.

Pot No.	pH Value	Daily Water Requirement c. c.	Days of Tolerance 1st Grub (a)	Days of Tolerance 2nd Grub (b)
50c	1.9	0.35	2	2
50f	1.9	....	3	2
50	2.7	5.60	28	....
50a	2.8	7.56	45	....
50b	2.9	8.24	28	....
51a	3.3	7.63	29	....
51b	3.45	8.38	23	....
52a	4.10	14.90	45	....
52b	4.75	13.20	47	47
54a	5.20	9.00	29	....
53b	5.30	10.46	47	....
53a	5.60	13.44	29	....
54b	6.00	....	53	....

(a) In all the tests where the pH value was greater than 1.9, the grub was alive at the time the above notations were made, but dead or missing at the time of the next observation.

(b) The data in this column relate to cases where a second grub was placed in the soil of that pot.

following such elevations of temperature. These rises in temperature also caused a more rapid evaporation of moisture from the various soils, especially the less acid ones; these as shown in the tables, had a much greater daily moisture requirement than the more acid soils. This variation in moisture content also undoubtedly had some effect upon the grubs.

Wireworms and Cutworms.

In order to obtain an idea as to the toxicity of acid soil to some other soil insects, several larvæ of both wireworms and cutworms were placed, along with the grubs, in some of the more acid soils of the preceding white grub experiments. In

general the observations showed that acid soil is just as toxic to these insects as to the grubs and ants. When the soil was less acid than is indicated by a pH value of 2.7, little if any toxicity was noted; when the acidity was greater than that indicated by a pH of 1.9, the soils were very toxic to these larvæ.

Nesting Reactions of Ants to Acid Soils.

In order to determine whether acid soils exert any repellent or attrahent effect upon the nesting activities of these ants, a series of soils ranging in pH value from 2.0 to 6.6 were prepared. Four small jars were filled with stocks of acid soil the pH values of which were 2.0, 2.8, 6.2, and 6.6, respectively. They were then made up to equal moisture contents and placed side by side in a large glass jar. Each small jar was covered with a piece of cardboard in which there was a perforation through which the ants could enter. The chief purpose of this cover was to retard evaporation from the soil. Granulated sugar was placed on each cover to serve as food. Thirty active ants (*Formica fusca subsericea*) were placed in the outer jar, which was then covered with a tight fitting lid of window screen to prevent their escape. Daily observations were made to note which jars the ants were selecting for nesting purposes. Although they made some shallow burrows in the most acid soil, they did not form or maintain an active nest in it. In all the other jars, they built nests and, even in the soil where the pH value was 2.8, they seemed fully as active as in the less acid soil. From this it would appear that soil as acid as 2.8 pH does not exert a repellent or attrahent action upon these ants. However, soil with a pH value of 2.0 did seem to have a repellent effect upon them.

Toxicity to Insects of Soils Treated With Sulfur.

In testing the toxicity of soil treated with sulfur to insects, both grubs and ants were used. A small quantity of air-dry soil was placed in each of several small containers. The soil of each was then treated with a previously determined quantity of flour of sulfur. In all cases the sulfur was intimately mixed with the soil. After adding the same quantity of water to each soil the insects were introduced. Observations were then made from time to time as to whether soils treated in this manner exerted any insecticidal effect upon the insect in question.

From these observations deductions were made as to the toxicity to the insect of soils treated with sulfur.

Ants.

In testing the toxicity of sulfur treated soils to ants (*Formica fusca subsericea*), two series of experiments, consisting of 5 cages each, were performed. In each of these jelly glasses were used as soil containers. Equal quantities of air-dry soil, about neutral or slightly acid in reaction were placed in each tumbler. The soils were then made up to approximately the moisture content which is optimum for plant growth, and an equal number of ants were placed upon the soil of each container. Each tumbler was then partially covered with a small piece of cardboard, to prevent so rapid evaporation of the moisture.

Each tumbler was placed upon a block of wood in a large pan and surrounded with water nearly to the depth of the block, to prevent as far as possible the escape of the ants. A small quantity of granulated sugar to serve as food was placed on the block upon which the tumbler was set.

After the ants had burrowed into the soil and established nests, the soil in four of the containers in each series were treated with sulfur at the rates of 1,000, 3,000, 5,000, and 10,000 pounds per acre respectively. The other soil in each series was left untreated to serve as a check. Flour of sulfur was used in one of these series and inoculated flour of sulfur in the other.

As in the preceeding experiments, the moisture content was in each case kept fairly constant by frequent weighings and the addition of water when necessary.

Observations were made from time to time as to the activity of the ants. On March 26, 45 days after the ants had been placed in the cage, evidence of activity on their part was noted in all the soils, and it seemed to be just as great in some of the most heavily treated soils as in the checks. From these tests it would seem that sulfur does not at once exert an appreciable insecticidal effect upon this species of ant.

White Grubs.

In testing the toxicity of soil treated with sulfur to the common white grub (Phyllophaga Sp.), cage experiments similar to those in the preceding ant experiments were used. The soils of these cages were prepared from stocks of soils which had been made acid, as noted before, by treating them with solutions of sulfuric acid.

Two series of experiments (Known as Series D and Series E), each of which consisted of five soils ranging in pH value from 2.5 to 6.3, were prepared. The soil of each pot of Series D was treated with ¼ gram of sulfur to each 100 grams of air-dry soil, a quantity equivalent to 5,000 pounds per acre; that in Series E was treated with four times as much, or 1 gram, which was equivalent to 20,000 pounds per acre. One grub was placed in each pot, and food was supplied through the use of grass roots, corn kernels, or corn seedlings. These experiments were run from June 27 to July 7, or a period of ten days.

TABLE VI.

DATA RELATING TO EXPERIMENTS ON THE TOXICITY OF SULFUR-TREATED
SOILS TO WHITE GRUBS.

SERIES D; ¼ GRAM OF SULFUR PER POT			SERIES E; 1 GRAM OF SULFUR PER POT		
Pot Number	Average pH of Soil	Days to Death of Grub	Pot Number	Average pH of Soil	Days to Death of Grub
50 D	2.6	2	50 E	2.4	1
51 D	4.2	(a)	51 E	3.7	(a)
52 D	5.4	(a)	52 E	4.9	(a)
53 D	5.5	10	53 E	5.3	(a)
54 D	6.3	(b)	54 E	6.2	(a)

(a) Grub living at the end of the experiment.
(b) No grub found at the time of the last observation.

Soils of varying acidities were used in these tests in order to ascertain whether the initial acidity of the soil would in any way affect sulfur so as to produce immediate insecticidal properties. The data of these experiments are presented in Table VI.

In each series the soil with the greatest initial acidity, though the same quantity of water per gram of soil had been used in its preparation, seemed much more watery than any of the other soils. In fact this soil in each series was decidely sloppy; it is thought that this condition, rather than the sulfur, caused the death of the grubs in the most acid soils.

From the table it can be seen that in the two series seven of the ten grubs lived 10 days and only one of these seven was dead at the termination of the experiment. The six living grubs were very active, even though, in some cases, the feeding conditions were not entirely satisfactory.

Since the death or disappearance of the insect could not, in any case, be ascribed to the sulfur, the conclusion was reached, that sulfur when applied to the soil in which grubs or ants are working has no direct or immediate effect which can be utilized insecticidally against these insects.

INSECT INFESTATION OF ROOT CROPS GROWN ON SOILS TREATED WITH SULFUR.

Several series of plot experiments were run in the summers of 1923 and 1924 in order to find out if sulfur, when applied to soils in much the same manner as that where it is used in the control of potato scab, would in any degree effect the control of insects commonly infesting some truck garden crops. Radishes, turnips, and potatoes were used in these tests. The details and results of these experiments are given in the succeeding pages of this paper.

Radishes.

Three series of plots eight feet square were utilized in the summers of 1923 and 1924 to determine what effect sulfur treatments would have on the degree of infestation of radishes by the maggots, *Hylemyia fusciceps* and *Hylemyia brassicea*.

The experiments, the data of which are given in Tables VII and VIII, were located on a tract of lowland soil near the university. This place was chosen on account of its availability and because the soil seemed to be very fertile, and therefore a good place in which to grow root crops.

To prevent drainage from one plot to another, the plots were slightly elevated by using the soil from lanes, or shallow ditches, 3 to 4 feet wide between them. These ditches seemed effectively to take care of the surface drainage.

In 1923 the amounts of sulfur indicated in Table VII were applied uniformly to each plot, and worked into the surface of the soil by means of a garden rake before the radishes were sown. In this series of plots the seed was sown broadcast and the soil was not there-after cultivated.

The hydrogen-ion concentration of the soil of each plot was determined before the applications of sulfur were made, and at intervals in the summer until the termination of the experiment. The pH values given in the table are those determined from the samples taken at the beginning of the tests, and just before the radishes were pulled.

As shown in the table, the acidity of the soil was not, in any case, very much increased by the sulfur. Inoculated sulfur gave a slightly greater increase in acidity than uninoculated flour of sulfur.

Since the acidity of the soil of the plots in the 1923 series of tests was not increased as much as was anticipated, another

TABLE VII.

DATA RELATING TO EXPERIMENTS IN 1923 ON THE DEGREE OF MAGGOT INFESTATION OF CHINESE WHITE RADISHES ON SOILS TREATED WITH SULFUR.

Plot No.	pH June 27 (a)	Quantity of Sulfur Applied (Pounds per Acre)	Average pH August 20 (a)	Number of Radishes Pulled	Radishes Infested by Maggots	
					Number	Percent
45	7.3 7.4	200	7.1 7.3	162	82	50.61
46	7.3 7.3	500	7.1 7.2	156	66	42.31
47	7.3 7.3	Check	7.3 7.3	157	47	29.93
48	7.3 7.3	1,000	6.8 7.2	167	23	13.78
49	7.3 7.2	Check	7.3 7.3	147	20	13.61
50	7.3 7.3	500 (b)	7.2 7.4	160	18	11.25
51	7.2 7.3	2,000 (c)	6.6 6.8	74	7	9.46

(a) The upper figure for pH value in each case is for the surface (less than two inches in depth), and the lower for the sub-surface (two to four inches in depth).

(b) This plot was treated with flour of sulfur instead of inoculated sulfur.

(c) Plot 51 was seeded about two weeks later than the other plots.

series of experiments on the same plots was carried out during the summer of 1924. The results of this series of experiments are given in Table VIII.

The soil of each plot was prepared by means of a small garden plow in such a way as not to disturb the arrangement of the plots of the previous season. As indicated in the table, the same quantity of sulfur was applied to each plot, as in 1923. Plot No. 45 was not included in the series of experiments for 1924. Instead of one variety of radishes as in 1923, two

varieties were used in 1924. Instead of being broadcast the radishes were seeded in drills, thus making possible the cultivation of the surface soil while the radishes were small.

As shown in the table, the second year's treatments of sulfur, like those of the first, had little effect on the hydrogen-ion concentration. Just why these soils failed to respond more readily to sulfur treatments is not known. However, since the soil acidity was but slightly increased by the application of as much as 4,000 pounds of sulfur per acre, it was concluded that this soil was very highly buffered.

TABLE VIII.

DATA RELATING TO EXPERIMENTS IN 1924 ON THE INFESTATION BY MAGGOTS OF RADISHES GROWN ON SOIL TREATED WITH SULFUR.

Plot No.	pH Value May 8 (c)	Quantity of Sulfur per Acre (Pounds)	pH Value July 23 (c)	VARIETY OF RADISHES			
				Chinese White		Cincinnati Market	
				Radishes Pulled		Radishes Pulled	
				Number	Percent Infested	Number	Percent Infested
46	6.40	500	6.45	164	58.5	455	14.5
47	6.95	(a)	6.70	157	73.2	497	21.9
48	6.50	1,000	6.30	156	75.0	486	20.2
49	6.95	(a)	6.70	174	52.3	442	17.9
50	7.00	500 (b)	6.45	148	60.8	422	19.2
51	6.50	2,000	6.40	166	40.4	411	18.0

(a) These plots were checks and received no treatments of sulfur, but in other respects were handled just like the treated plots.

(b) Flour of sulfur was used on this plot instead of inoculated sulfur.

(c) These values were derived from determinations made upon a composite of several samples of soil, to the depth of 6 inches, taken at various places on each plot.

From the data of these two series of experiments, it is quite evident that control of root maggots, under the conditions of these tests, is not brought about by treating a soil with either flour of sulfur or inoculated sulfur.

In the summer of 1924 a third series of radish plots was arranged to test the effect of the residual acidity of a soil, which has become acid through the oxidation of elemental sulfur, upon the degree of infestation of radishes by root maggots.

Since the soils of two of the sulfur-treated plots of the 1923 series had become decidedly acid, one of each of the 5 plots of the series of 1924 was located at one end of each of the above mentioned turnip plots respectively.

The soils of these plots were prepared by means of a small garden plow, and then seeded to radishes without making any additional applications of sulfur.

The hydrogen-ion values given in Table IX are from a composite sample of soil taken from samplings made at four different places on each plot, about two weeks before the radishes were pulled.

The percentage of infestation given in the table are based on counts of from 225 to 250 radishes pulled at random from each plot. It is apparent that high soil acidity did not, in this case, bring about a control of root maggots. On the contrary, data in Table IX would seem to indicate exactly the opposite.

TABLE IX.

DATA RELATING TO MAGGOT INFESTATION OF RADISHES GROWN IN 1924 ON SOIL TREATED WITH SULFUR IN 1923.

Plot No.	Pounds of Sulfur per Acre Applied in 1923, Only	pH Value in 1924 at the Time the Roots were Pulled	Percentage of Maggot Infestation
100	669	5.7	51.1
101	(a)	6.2	59.73
102	1,333	4.7	69.51
103	(a)	6.1	66.21
104	2,667	3.9	81.08

(a) These plots were checks and had received no treatments with sulfuur.

However, the writer does not think such a conclusion should be drawn until more data are available.

Since the production of H_2S has been demonstrated in composts of manure, sulfur, and soil, it was deemed advisable to arrange a series of plots and to treat the soils of the different plots with varying quantities of manure and sulfur, and after seeding them to radishes to note if sulfur, under such conditions, produced any perceptible control of root maggots.

A series of eight plots similar to those the data of which are given in Tables VII and VIII, were prepared on a tract of ground adjacent to the above mentioned plots. Sulfur and manure, as noted in Table X, were applied to the surface of each soil and worked into it by spading the plot to the depth of 6 or 8 inches.

The data in the table are based on counts of the number of radishes showing injury by maggots at the time the crop was

harvested. From the percentage of infestation of the radishes on the different plots it is very evident that the treatments of sulfur and manure did not, under the conditions of this experiment, effect a control of root maggots.

Turnips.

During the summer of 1923 six plots, each 16 by 48 feet in size, were prepared. The plots were arranged as nearly as possible so that the check plots alternated with those treated with sulfur.

TABLE X.

DATA RELATING TO MAGGOT INFESTATION OF RADISHES GROWN ON SOILS TREATED WITH MANURE AND SULFUR.

Plot No.	pH Value July 23	Quantity of Sulfur (Pounds per Acre)	Number of Radishes Pulled	Percentage of Infestation
26 (a)	6.9	500	369	85.9
27 (a)	7.0	1,000	407	81.8
28 (a)	6.95	(c)	450	80.9
29 (a)	6.9	2,000	426	72.3
30 (b)	6.9	500	425	80.7
31 (b)	6.8	1,000	452	75.0
32 (b)	6.8	(c)	579	70.8
33 (b)	6.7	2,000	410	74.4

(a) The plots thus designated in the table received an application of one bushel of manure per plot, or an amount equivalent to 9.7 tons per acre.

(b) These plots received an application of two bushels per plot.

(c) These plots were checks and were not treated with sulfur.

In preparing these plots each one was plowed as a back-furrow, thus leaving an open dead furrow between successive plots. These furrows took care of the surface drainage, thus preventing water from running from one plot to another.

After the plots had been prepared they were treated with the quantities of sulfur noted in Table XI. This sulfur was applied broadcast, as evenly as possible, and worked into the surface of the soil with a garden rake. The turnips were then seeded broadcast, care being taken to use about the same quanity of seed on each plot.

A few observations were made from time to time in the course of the experiment but the percentage of infestation given in the table are based upon counts of the number of turnips showing signs of injury by the maggots at the time they were pulled.

As can be seen from the table, there was no significant variation in the degree of infestation of the turnips on the treated as compared with the untreated plots. While the average percentage of infestation on the two check plots was less than that on the treated plots, the percentage of infestation of one of the

TABLE XI.

DATA RELATING TO MAGGOT INFESTATION OF TURNIPS GROWN IN 1923 ON PLOTS OF SOIL TREATED WITH SULFUR.

Plot	Sulfur Pounds	pH (a) Value	Number of Turnips			Turnips Russeted		Weight of Turnips Pulled	
			Pulled	In-fested	Per-cent	Num-ber	Per-cent	Total Grams	Average Grams
100	669	5.3 5.8 5.8	1321	216	16.35	205	15.52	49,305	37.32
101 (b)	....	5.9 5.9 5.9	2372	238	10.03	0	......	102,770	43.33
102	1333	3.5 5.4 5.7	1244	203	16.32	1088	87.46	5,550	44.50
103 (b)	....	5.9 5.9 5.9	1107	189	17.07	0	......	59,685	53.92
104	2669	4.1 5.1 5.9	1087	253	22.91	651	59.89	38,950	35.02
110 (c)	669	.... 5.5 5.5	672	236	35.12	265	39.43	19,155	28.50

(a) The upper number in each case is for the surface inch of soil, the second for the first 2 inches of surface soil, and the lower one for the sub-surface, (2 to 4 inches deep).

(b) These plots were checks and received no treatments with sulfur.

(c) This plot was treated with flowers of sulfur instead of inoculated sulfur.

checks was greater than that of two of the treated plots. With the exception of the plot treated with flowers of sulfur, the difference in degree of infestation on the checks and treated plots was rather small. If the data of this series of experiments indicate a tendency in any direction, they seem to show that sulfur increased rather than decreased the degree of infestation by root maggots. However, the writer does not consider the

difference in degree of infestation of the treated and untreated plots either great enough or consistent enough to warrant such a conclusion. It is, however, safe to say that treatments with sulfur did not in this case effect a control of root maggots.

The percentage of infestation on the plot treated with flowers of sulfur was considerably higher than those of either the check plots or the plots treated with inoculated sulfur. The writer has no satisfactory explanation for this difference. This plot was slightly more sandy and gravelly than the others, and this may have in some way favorably influenced the flies.

As shown in the table, the acidity of the soil of the plots treated with sulfur, expecially within two inches of the surface, was greatly increased. In general, the apparent size of the turnips on the plots treated with sulfur was slightly less than those on the check plots. The figures for the average weight of the turnips on the various plots Table XI, as well as the pictures of the turnips Plate I, Fig. A, also show this to some extent. Aside from this, only slight differences, if any, in the growth of the turnips on the several plots were noted in this season.

Potatoes.

In the spring of 1924 a tract of grass land which had been farmed several years ago was found to be somewhat heavily infested with the common white grub. Since these grubs frequently cause an appreciable amount of injury to potatoes, the writer decided to run some experiments on this tract of ground to see if inoculated sulfur had any value as a control for white grubs.

This tract of land was broken as soon as the frost was out of the ground, and the soil in proper condition to be worked. After having been properly prepared, it was divided into four plots each 66 feet long and 33 feet wide. These plots were arranged end to end, and the rows on them so planned that it was possible to cultivate from one end of the series to the other, thus facilitating their care.

When applying the sulfur and planting the potatoes it was noted that the soil of Plot 203 was somewhat heavier than that of the other plots; this plot was therefore divided and one half of it left untreated to serve as an additional check. This plot was given the number 203A.

With the exception of plots 203 and 203A, a lane 8 feet wide was left between successive plots; drainage ditches were also

TABLE XII.

DATA ON INVESTIGATIONS IN 1924 OF THE EFFECT OF SULFUR UPON THE AMOUNTS OF WHITE GRUB AND SCAB INJURIES TO POTATOES GROWN ON SOILS TREATED WITH SULFUR.

Plot No.	Sulfur Pounds per Acre	Ph Value at		Early Potatoes (Red River, Early Ohio)			Yield		Late Potatoes (Irish Cobblers) Percentage of Injury			
		Beginning	End	Yield Pounds per Plot	Percentage of Injury		Pounds	Number	By Weight		By Number	
					By Grubs	By Scab			Grubs	Scab	Grubs	Scab
200	(a)	6.5 6.5	6.5 6.8	889.5	9.8	80.4	199	1496	17.6	7.54	17.3	5.4
201	200	6.5 6.5	6.2 6.2	822.0	11.2	79.0	175	1351	20.0	57.20	21.20	50.20
202	500	6.5 6.5	0.0 0.0	641.6	11.9	75.6	140	1049	27.2	56.40	24.30	50.00
203	1,000 (b)	6.5 6.5	4.4 5.5	713.6	13.5	51.3	138	964	15.0	12.90	31.10	26.00
203A	(a) (b)	6.5 6.8	6.5 6.8	801.0	10.5	63.3	184	1352	10.9	9.30	22.90	16.00

(a) These were check plots and received no sulfur treatments.

(b) Since these were just half the size of the other plots, all figures for them which indicated yield, injury, and infestation were multiplied by two, in order that their data would be comparable with that of the other plots, and the percentages were then figured.

(c) The upper figure for pH value in each case is for the surface two inches of soil and the lower one for the sub-surface (2 to 4 inches in depth).

provided at the edge of the various plots, to prevent the surface drainage of one plot from flooding the plot adjoining it, thus interfering with the tests.

The reaction of the soil was determined by colorimetric hydrogen-ion tests, both before the sulfur was applied and at the time the potatoes were dug. A few determinations of pH value were made at other times in the growing season but their results are not given in this paper.

Sulfur was applied to plots 201, 202, and 203, before the potatoes were planted, at the rate of 200, 500, and 1,000 pounds per acre, respectively. These applications were made broadcast over the surface of each plot and the sulfur was then worked into the soil by means of· a wheel-hoe, in order to insure, a more rapid reaction between it and the soil.

Two varieties of potatoes were used on each plot. Six rows of the early variety and four of the late one were planted upon each plot. As both varieties were procured on the local vegetable market, the writer does not vouch for their purity. The early variety, which was called Red River Early Ohio, matured about the last of August, and the late one, which was thought to be Irsh Cobblers, matured 2 or 3 weeks later.

Since sulfur is supposed to be effective in controling scab (Phytoptera infestans) on potatoes, observations were also made as to the percentage of potatoes that showed scab lesions at the time the potatoes were dug. The data relating to both of the above types of observations are found in Table XII.

Preliminary observations were made at several times throughout the season, but the data given in the table are based on counts and weights taken at the time the potatoes were dug. As shown by the data the amount of injury caused by grubs was slightly greater on the treated plots than on the check plots. It is, therefore, concluded that sulfur, when applied as in this case, does not exert any insecticidal effect on the common white grub, even when applied at a rate as high as 1,000 pounds per acre.

SCAB INFESTATION OF POTATOES.

As stated before observations were made at the time the potatoes on the preceding plots were dug as to the amount of scab infestation. From the data, Table XII, it will be seen that there was considerable variation in the degree of scab infestation on the various plots. Although, in case of both

early and late potatoes, the plot which had received the heaviest treatments of sulfur had less scab than the other treated plots, some of the checks had decidedly less scab than the adjacent treated plots.   The late potatoes on both the check plots had less scab than those on any of the sulfur treated plots.   In the case of the early potatoes, though plot 203 which had received the heaviest treatment of sulfur had the least scab, the untreated end of what was originally the same plot (Plot 203A) had from 12 to 16 per cent less scab than the other two plots which had been treated with sulfur, and 17 per cent less scab than the other check which had a slightly greater amount of scab than the adjacent sulfur-treated plot.

It is evident that scab was not very effectively controlled by these sulfur treatments.   On some of the plots it would seem that treatment with sulfur increased rather than decreased the degree of infestation by scab.

In most cases the infestation with scab was not so severe as to destroy the usefulness of the potatoes, and would probably not have seriously affected the salability of the crop.   In this respect, however, there was no difference between the check plots and those treated.

Sulfur as a Carrier for Other Insecticides.

A preliminary test was made in which quantities of both sulfur and lime were impregnated with carbon bisulfide and nicotine sulfate, and applied to nests of ants (*Formica fusca subsericea*).   Since there was no indications of insecticidal promise, this phase of the investigation was carried no farther.

Sulfur as an Insecticide for the Control of Subterranean Aphids.

As stated previously, difficulties in handling the root aphis were encountered in some preliminary tests; and as a result, work with this group of insects was practically abandoned. However, in the summer of 1924, through the courtesy and cooperation of Dr. C. R. Cutright, of the Ohio Experiment Station, an opportunity was afforded to test sulfur as a control for the black peach aphis.

The detailed procedure and results of these tests are given in Bulletin 387 of the Ohio Experiment Station.   For that reason only a general account of the experiments and results will be given here.

In these tests a number of peach trees in a young orchard, which had just been planted, were treated with quantities of inoculated sulfur ranging from ½ pound to 16 pounds per tree. The sulfur was worked into the soil about the base of each tree to a depth of from 3 to 6 inches. An area of about 18 inches square, or 2¼ square feet, about each tree received treatment.

The reaction of the soil in the area treated, around each tree, was ascertained by colorimetric hydrogen-ion determinations, both before and at times in the course of the experiments. These observations were made in connection with observations of growth and of insecticidal conditions, at intervals throughout the season. The data for hydrogen-ion concentration determinations are given in Tables 2, 3, and 4, pages 220 and 221, of the above mentioned bulletin. Toward the end of the summer there was a considerable rise in the pH value of the soil around several of the trees. It was thought that the cultivation of the soil had probably mixed untreated soil with that which had been treated, and thus helped to cause a decrease in the soil acidity, as shown in the table. On October 6, when the final observations were made by Dr. Cutright, more than half of the treated trees were found dead. Living aphids were found at this time on one of the living trees. From a consideration of these facts it is evident that sulfur cannot be used as a control for the black peach aphis.

The Effect of Sulfur Treatments Upon Plant Growth.

While observations were being made on the insect infestation of root crops grown on field plots treated with sulfur, observations were also made on these same plots on the effect of treatments with sulfur upon plant growth. A general summary of these observations are given in the following paragraphs.

From Plates II and III, and from the data as to yields and weights of crops (Tables XI and XII), it is apparent that the effect of sulfur upon plant growth is variable, depending largely upon the reaction of the soil before the treatments and the extent to which the soil is buffered. None of the treatments with sulfur on the highly buffered lowland soils, the data concerning which are given in Tables VII, VIII, and X, had any appreciable effect upon the growth of radishes.

In Plate II are presented pictures of a series of radish plots which had been treated in 1923 with the quantities of sulfur

set forth in Table VII, and were treated with like amounts of sulfur in 1924, as shown in Table VIII. The stakes driven in the various plots are so marked as to indicate the approximate average height of the radishes in inches.

From the plate it is evident that the treatments with sulfur had little, if any, effect upon the top growth of these radishes, even where sulfur was applied in quantities as great as 2,000 pounds per acre for two successive years. The radishes were not weighed, but there was no apparent effect on the root growth. No russeting was apparent on any of the radishes or turnips grown on these lowland soils.

On less highly buffered upland soil, the effect of sulfur treatments upon plant growth was considerably more pronounced. On the turnip plots, the data of which are given in Table XI, such treatments did not conspicuously influence the top growth. In the following year, however, there was a very pronounced effect on the top growth of radishes and turnips on a series of plots (Table IX) arranged on one end of the turnip plots just mentioned, even though no additional sulfur treatments were made. In Plate III are shown pictures of these radish and turnip plots. The hat in the picture is on the line between the radishes and turnips on each plot. In the back ground of each picture, in the area marked A, is shown a portion of the previous year's turnip plots which were not included in the series of 1924. This portion of the 1923 series of plots showed very definitely that sulfur when applied to soils such as this, is very decidedly detrimental to the growth of weeds.

In the summer of 1924 Dr. D. M. DeLong planted beans on some of the unused portions of the above mentioned turnip plots and here, also, the residual effect of the sulfur treatments of 1923 was very decidedly unfavorable to the growth of plants. Even one not familiar with the location of the plots of the 1923 series, which had been treated with sulfur, could very readily point out the place where the sulfur, especially in quantities equivalent to more than 500 pounds per acre, had been applied.

The effect upon root growth was also more pronounced on the upland than upon the lowland soils. In Table XI is given the average weight of turnips on the plots treated with sulfur in 1923. Although the variation in size, as shown by the table, is not so very pronounced, it is evident that sulfur had a detrimental effect upon root growth of the turnips.

The most conspicuous effect upon the turnips of this series was that which the writer has termed "russet". In Plate I, Figure A, is shown a series of typical turnips from the various plots the data of which are given in Table XI. The darkened, chapped appearance at the top of the turnips is "russet". This so-called russet apparently occurs for the most part in approximately the surface inch of soil. As set forth in the table, russeting was more pronounced where the application of sulfur was heaviest. The turnips on the check plots showed no sign of this condition.

On the plots where 1,000 pounds of sulfur per acre was applied many of the turnips would not have been readily salable. On the radish and turnip plots, of 1924 Table IX, on the same soils no russeting was evident, although the sulfur was very detrimental to the growth of the crops.

Sulfur had no apparent influence on the top growth of potatoes, but as shown in the figures for yield, Table XII, there was a decrease in yield, in terms of both number of potatoes and pounds per plot, as the quantity of sulfur per acre was increased. In particular there was a conspicuous difference between the yields from plots 203 and 203A, which were in reality parts of the same plot as originally laid out.

From the forgoing data it is evident that in cases where the soil is not very highly buffered sulfur is likely to be detrimental to plant growth.

SUMMARY.

1. Although SO_2 and H_2S were considerably toxic to ants when bubbled into a soil from a generator or storage tank, no evidence was found to indicate that either of these substances could be readily produced in a soil in sufficient quantity to be of insecticidal value.

2. H_2SO_3 and H_2SO_4 are toxic to ants (*Formica fusca subsericea*) when applied in sufficient quantity to a soil in which the ants have made their nests. However, the quantity necessary is greater than one might readily hope to obtain through the oxidation of sulfur in the soil.

3. Ants, white grubs, wireworms, and cutworms are able to live for a considerable time in soils with an acidity as great as that indicated by a pH value of 2.8. Such a degree of acidity would kill most of the vegetation of a soil and, even where the initial reaction was decidedly acid, would be attainable only through the use of more than 2,000 pounds of sulfur per acre.

4. Ants do not appear to be attracted to or repelled from nesting in a soil until its pH value is less than 2.8.

5. Applications of flour of sulfur and of inoculated sulfur do not seem to be toxic to ants, grubs, or root maggots; and, when applied to soils in which truck crops are grown, do not exert any appreciable insecticidal influence. Such applications, if they have any effect, seem slightly to increase maggot infestation of turnips and radishes rather than decreasing it. However, it is not thought that the data at hand is sufficient to warrant such a conclusion.

6. Sulfur did not prove effective as a control for the black peach aphis, but was very detrimental to young peach trees at Catawba Island, Ohio.

7. Sulfur was not found of any value as a carrier of insecticides such as nicotine sulfate or carbon bisulfide.

8. Sulfur was injurious to plant growth on soils which before treatment had a pH value of about 6.0 or less.

9. Scab (*Phytoptera infestans*) was not effectively controlled on potatoes, even in cases where as much as 1,000 pounds of sulfur per acre was applied.

CONCLUSION.

Since direct treatments of sulfur did not have any insecticidal effect upon ants or white grubs, since all of the forms of insects used tolerated a very high degree of acidity, and since in field tests sulfur showed no indications of insecticidal control, the conclusion seems inevitable that elemental sulfur can not, in light of our present knowledge, be considered to promise any value as a soil insecticide.

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EXPLANATION OF PLATES.

PLATE I.

(A) Turnips from each of the plots the data for which are presented in Table XI. The rough, dark portion on the turnip, a and a' in numbers 102 and 104, is russet. Numbers 101 and 103 are from check plots and received no sulfur treatments. Numbers 100, 102, and 104 were grown in soils which had received treatments of sulfur equivalent to 669, 1,333, and 2669 pounds per acre, respectively. Number 110 is from a plot which had been treated with a quantity of flour of sulfur equivalent to 667 pounds to the acre.

(B) The cages used in the experiments on ants (Formica fusca subsericea) Tables I and III.

PLATE II.

In this plate are shown the top growths of radishes grown on the series of plots the data concerning which are given in Tables VII and VIII. Numbers 47 and 49 received no sulfur treatments, while 46, 48, and 51 were treated with inoculated sulfur in quantities equivalent to 500, 1,000 and 2,000 pounds per acre in both 1923 and 1924. Plot 50 was treated with flour of sulfur at the rate of 500 pounds per acre. The numbers on the stakes in each plot represent in inches the height of the radishes. In each case the top of the stake is 18 inches from the surface of the ground.

PLATE III.

In this plate are shown pictures of the radish plots of 1924, the data for which are presented in Table IX, and some turnip plots from which no data were tabulated. These plots were located on one end of the turnip plots of 1923, the data for which are given in Table XI. No sulfur was applied to these plots in 1924, but they show the effect of the residual soil acidity caused by the sulfur treatments of 1923. Plot 101 received no treatment with sulfur, while plots 100, 102, and 104, as shown in Table XI, were treated in 1923 with inoculated sulfur in quantities equivalent to 669, 1,333, and 2,669 pounds per acre respectively.

This section designated (A) in each photograph is the unused portion of the turnip plots of 1923. In this portion is shown the effect of the residual soil acidity, due to the sulfur treatments of 1923, on weed growth. In sections (B) and (C) respectively, are shown the radish and turnip plots of 1924.
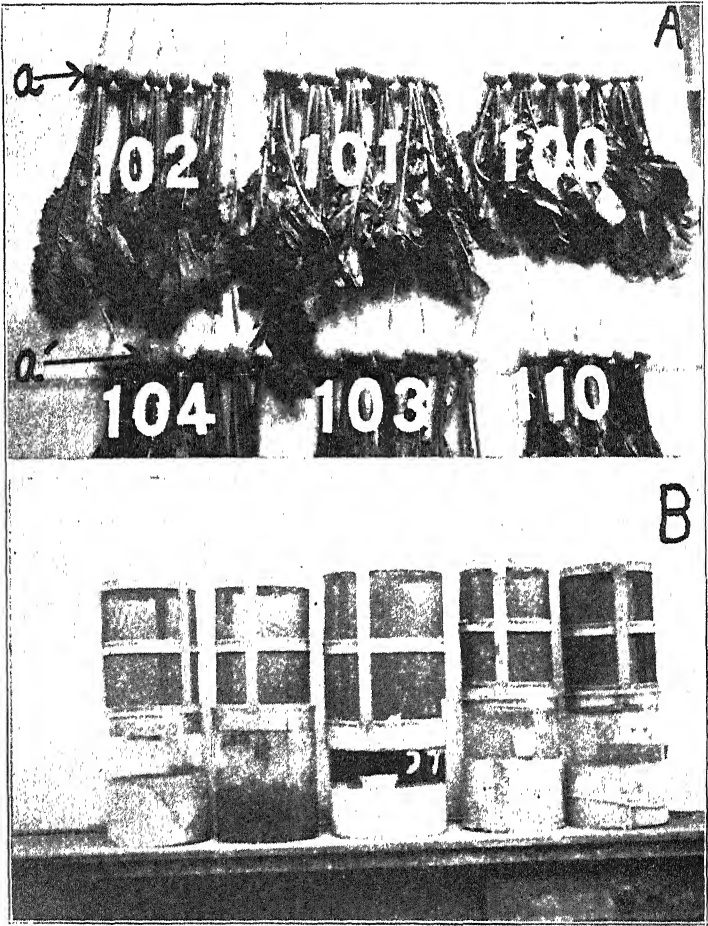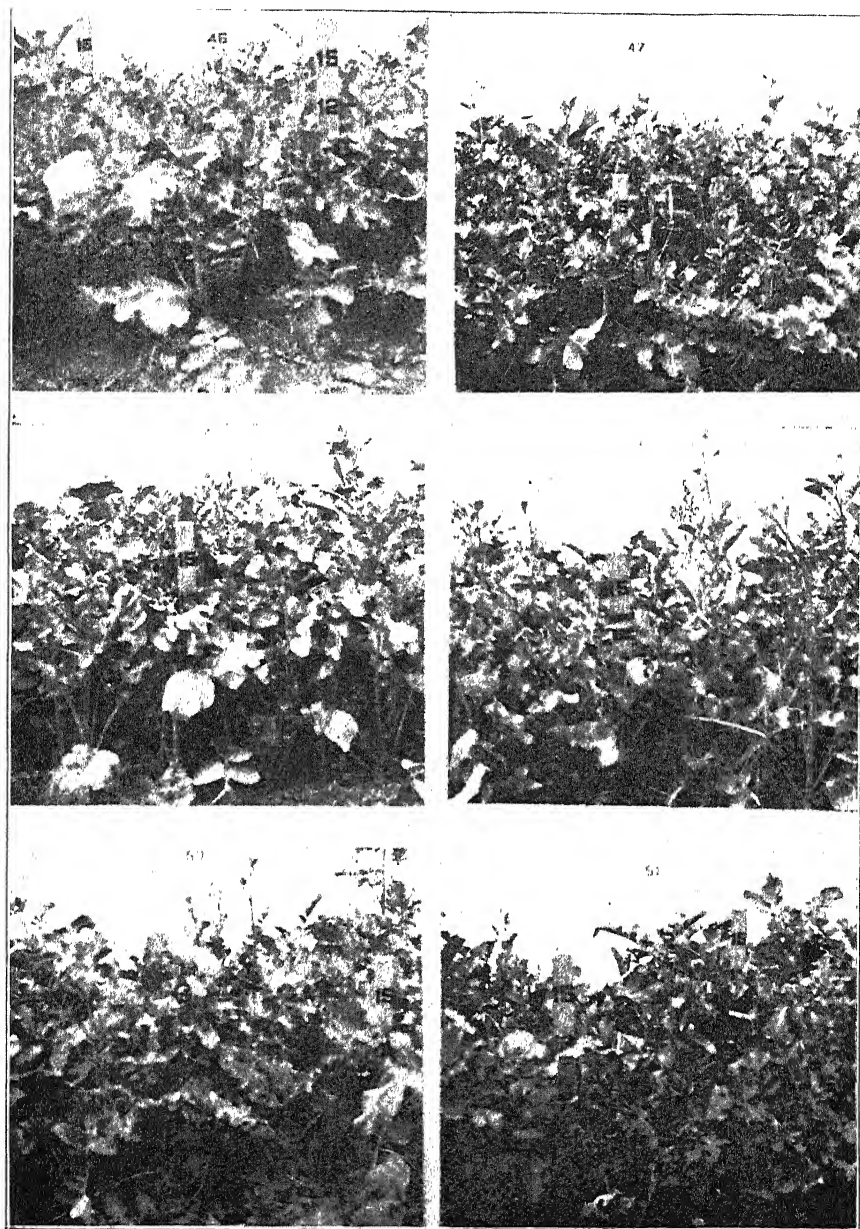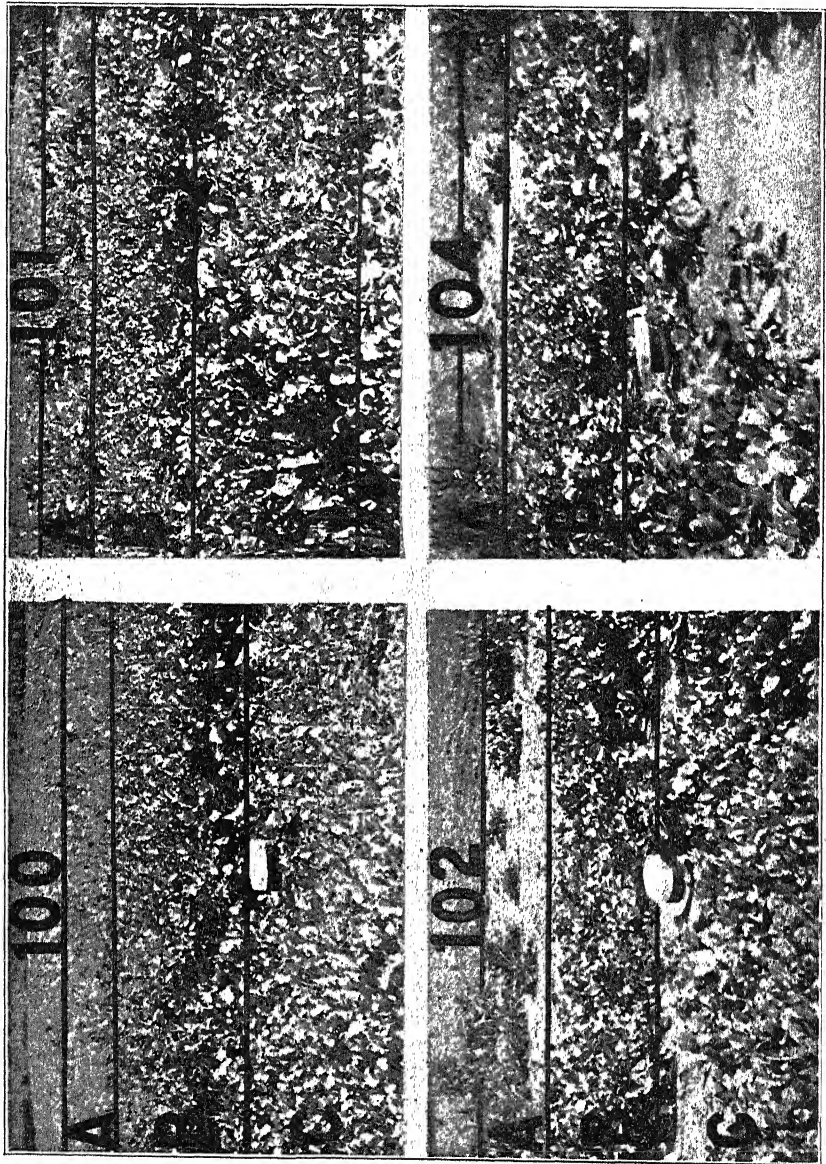
THE ROOTS OF WILD RICE.
ZIZANIA AQUATICA L.

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This grass grows from Maine to Minnesota in aquatic habitats (2 and 5). It is common in marsh lands all around the Great Lakes although rapidly being destroyed in a great many places by our civilization.

The roots of this plant when it is mature, as in a great many grasses, is an adventitious root system which is submerged. The roots are rather large having a diameter as great as three or four millimeters. The root cap is of small size and extends from the tip of the root for a distance of about three millimeters. The writer was not able to find any root hairs although the growing tips of the roots are usually imbedded in the mud.

Janczewski (3) describes five types of root development as follows:

1. The root tip is composed of four primary independent tissues: the rootcap, the epidermis, the cortex and the central cylinder.

2. The root tip is composed of three primary independent tissues: the rootcap, the cortex and central cylinder.

The epidermis is derived later from the cortex.

3. The three primary tissues are the same as in the second type, but it is the calyptrogen layer developing the rootcap which gives rise to the epidermis.

4. The primary tissues are at the tip in one meristematic region.

5. The root contains only two primary tissues: the central cylinder and cortex.

From all the data that the writer has been able to obtain the grasses belong to the first two groups. Zizania aquatica belongs to the second group.

The Cortex.

In a cross section of the mature roots of wild rice the cortex is very thick and with very large air spaces (Fig. 1). The epidermal cells are small cells and in the older roots are torn and destroyed (Fig. 1) by the increase in the periphery of the root.
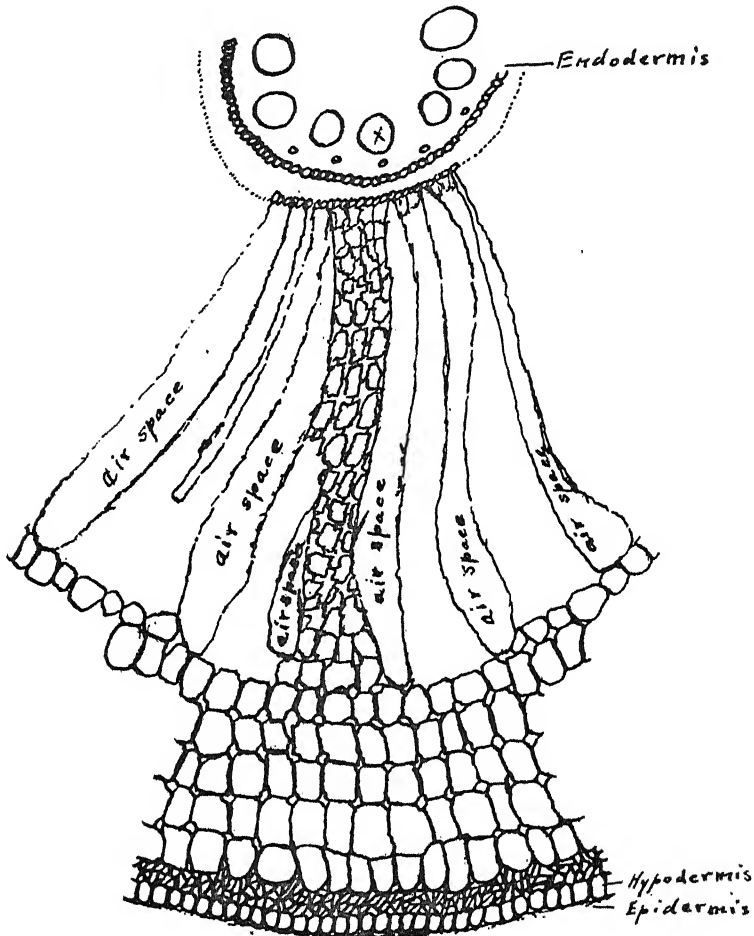

Figure 1

The hypodermis is composed of very large cells (Fig. 2) which apparently is the functioning epidermis of the older part of the root. Adjacent to the hypodermis there is a region, two or three cells in thickness (Fig. 2), which becomes lignified and functions as a mechanical tissue preventing the collapse of the aerenchyma of the cortex.

This aerenchyma of the cortex begins quite early by the pulling apart of the corners of the cortical cells. This continues with the enlargement of the cortex until the cells in the transverse section have the form of a cross (Figs. 3, 4, 5). The continuation of the enlargement of the cortex tears these cells apart completely, or actually destroys some of the cells, until the mature cortex shows radiating plates of cells with the larger cavities bordered with the torn fragments of cells (Figs. 6 and 1).
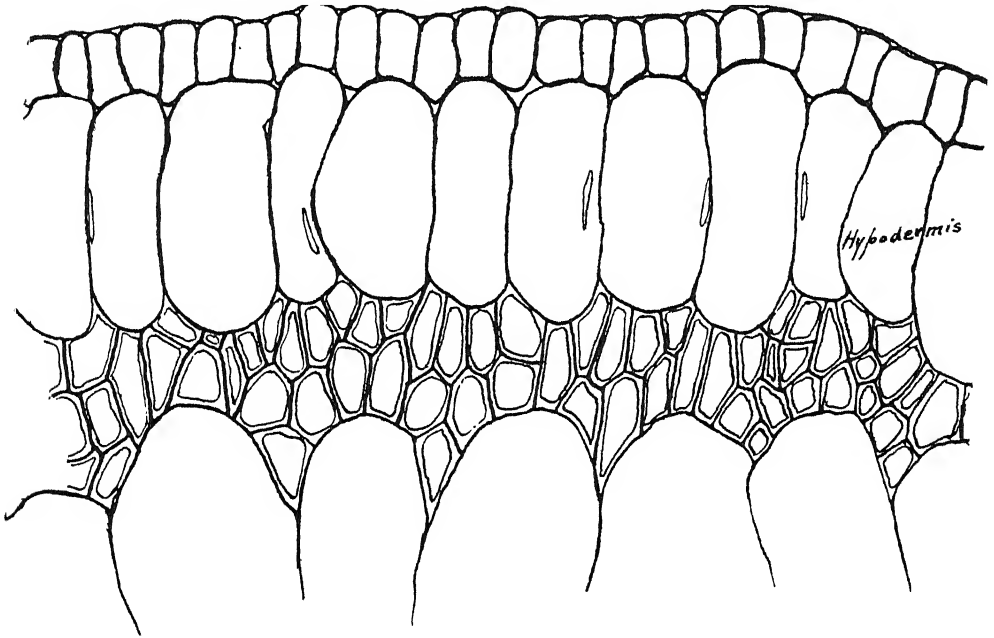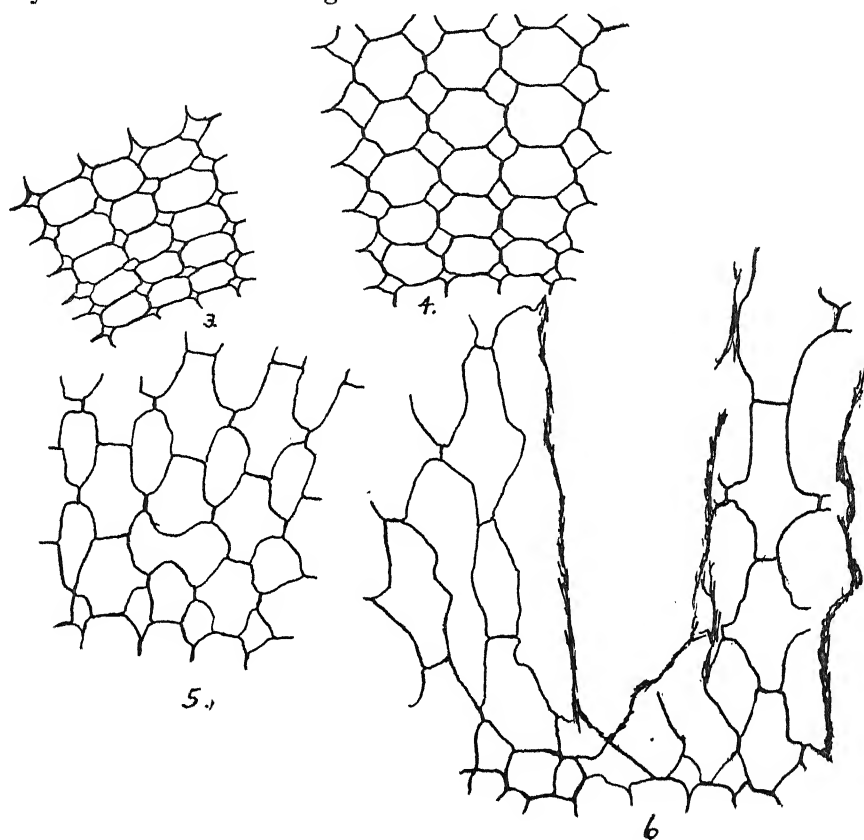

FIGURE 2

In the roots of Echinochloa walteri c. lysigenous formation of the larger cavities does not occur and is entirely schizogenous.

THE CENTRAL CYLINDER.

The central cylinder is quite easily seen in cross section at the tip of the root (Fig. 7). A very few cells from this toward the stem are the cells which finally become the so-called metaxylem vessels. They are enlarged and are easily distinguished because of this from the other cells of the central cylinder (Fig. 8). The protoxylem cells are differentiated centrifugally from these and are formed by the pericycle (Fig. 9). These cells are the first cells to have their walls thickened (Fig. 10) and because this

deposition occurs at the beginning of the region of elongation of the root, these protoxylem vessels become spiral vessels (6 and 1). Lignification begins in these cells and the surrounding cells and continues centripetally until all of the central cylinder is somewhat lignified.

FIGURES 3, 4, 5, AND 6

DIFFERENTIATION OF XYLEM.

A number of our books state that one of the differences between stems and roots is that the primary xylem cells are formed centripetally in roots. Jeffrey (4) states that it may occur in both directions. However, if we consider the morphological changes in growth from meristematic regions to be: (1) cell divisions, (2) cell enlargement and elongation, and (3) maturation (or differentiation), then it is certain that in grasses the primary xylem is centrifugal in its development although lignification occurs centripetally.
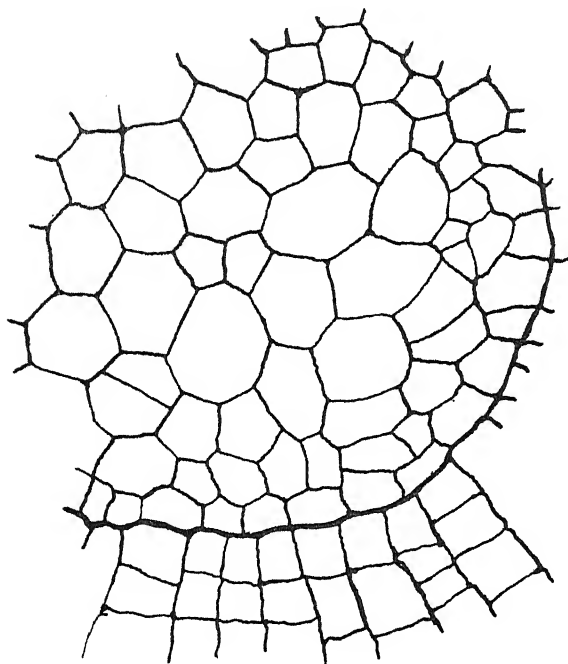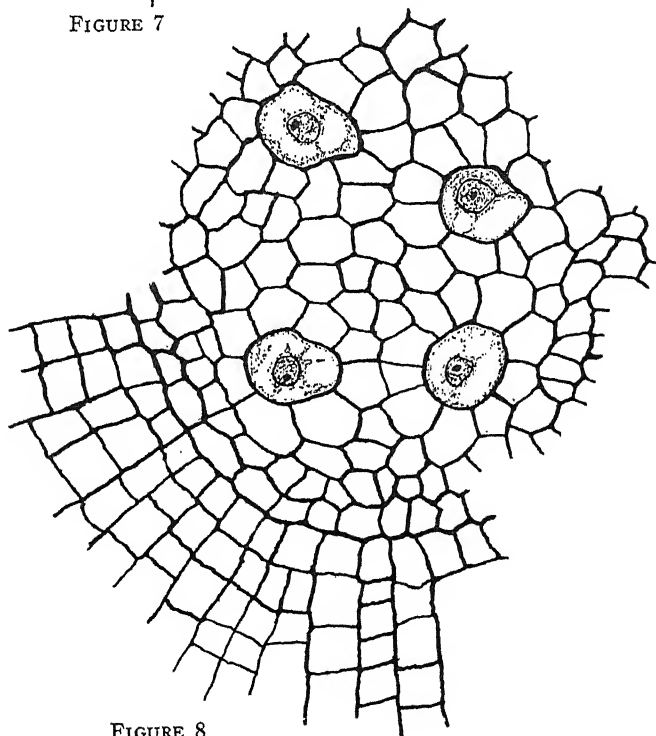
FIGURE 7

FIGURE 8

Other monocotyledonous plants examined by the writer indicate that the above development is not peculiar to the grasses as a group. The only records obtained by the writer on this point from the literature is that of Janczewski (3) in which he states that the metaxylem vessels are the first to be seen in the root tips of Fagopyrum, Pistia, Hordeum, Hydrocharis and Pisum.
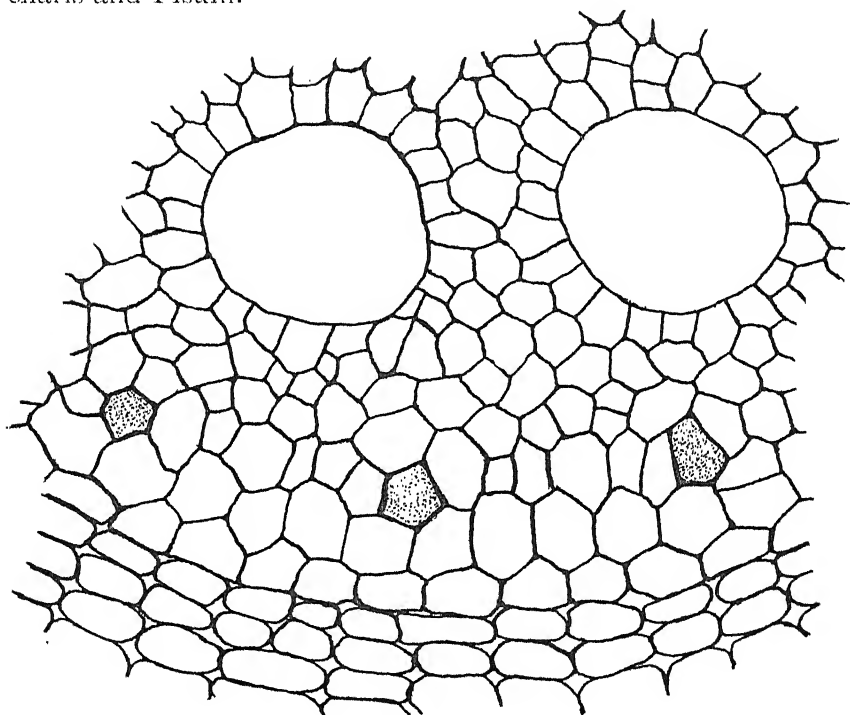
FIGURE 9

There is little doubt in the mind of the writer that the development of the primary xylem of roots is centrifugal although lignification is centripetal.

SUMMARY.

1. The formation of the air passages in the roots of Zizania are first schizogenous and finally lysigenous.

2. The epidermis is a layer of small cells, and the hypodermal cells become quite large in comparison, functioning as the epidermis because of the destruction of the epidermal cells.

3. Adjacent to the hypodermis there is a band of sclerenchyma which stiffens the outer cortex apparently preventing the

collapse of the inner cortex which is mostly aerenchyma.

4. The xylem is centrifugal in development. (a) The largest water vessels are the first to be differentiated and are nearer the center of the root. When mature they are reticulate or pitted.

(b) The second water tube is formed from the pericycle and becomes a spiral vessel, or when elongation is slight is a reticulate vessel.
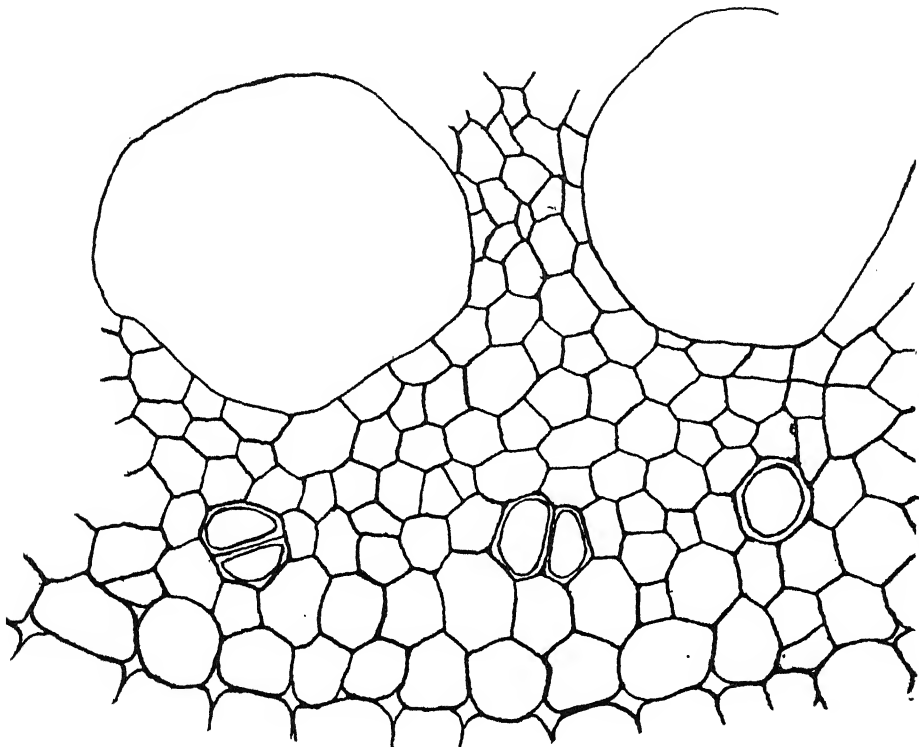
FIGURE 10

5. The second and smaller water tubes are the first lignified. Lignification then progresses toward the center of the cylinder.

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SPERMATOGENESIS IN BRANCHIPUS VERNALIS.

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PART II.

THE PRIMARY SPERMATOCYTE.

In a previous paper, Baker and Rosof, No. 1, 1927, the general description of the testes and the behavior of the chromatin of the spermatogonia in Branchipus was reported. The salient features of the behavior of chromatin in the spermatogonia may be summarized as follows: (1) There are twenty-three chromosomes in the spematogonium of Branchipus vernalis; (2) There are eleven pairs of homologous chromosomes and one accessory; (3) In the late prophase of spermatogonia, some homologous chromosomes become paired. This pairing is more of a chance occurrence than a regular behavior in the activity of chromosomes. The present paper is limited chiefly to the description of the observations covering the chromosomal transformations of the spermatocyte of the first order.

Following the formation of the clumped, darkly staining and dense chromosomal mass of the spermatogonial telophase, a series of transformations within the spermatocyte nucleus ensue. These changes involve both karyolymph and chromatin and result in the synapsis of homologous pairs of chromosomes. One of the factors of this behavior is the mutual attraction that synaptic mates have for each other in which they exhibit an affinity greater than that shown to the other chromosomes. This does not imply that the chromosomes which are not homologous have no attraction for each other, for an attraction between unlike chromosomes is evidenced, but this relation is of a different nature from that shown by like chromosomes. The attraction of dissimilar chromosomes for each other is indicated by the end to end association which is assumed by these chromosomes in the early prophase and which has an influence on the subsequent behavior of the chromosomes.

After the last spermatogonial division, the beginning of the changes which occur in the primary spermatocyte is indicated by the diffuse attenuated condition of the chromatin which simulates a disconnected reticulum. The delicate, ill defined attenuated strands, which extend from the irregular masses of chromatin, are intermingled and reveal no apparent definite arrangement. The reticulum that characterizes this early stage is effected by the separation of the chromosomes from the dense mass of the telophase plate of the last spermatogonial division. At this time, no apparent definiteness or order can be detected in the behavior of the chromatin, but with a more detailed study the successive changes in the progression of the formation of definite chromosomes are seen, (Figs. 1 to 16 inclusive).

The relationships of strands and masses of chromatin to each other as well as the rapidity with which homologous chromosomes synapse are dependent upon the arrangement and condition of the chromosome aggregates as the reticulum formation begins.

Figure 1 is a cell taken from a different cyst than are figures 2 to 5 inclusive. This nucleus shows thirteen masses of chromatin which are somewhat peripherally arranged. Two of these chromatin masses (d and e) are well defined while the remaining masses are irregular and diffuse. These are connected by communicating strands. The strands are not definitely oriented and the number of strands extending from the more conspicuous masses of chromatin vary.

Figures 2 to 5 inclusive are taken from the same cyst. Eighteen masses of chromatin are seen in the nucleus shown in figures 2. The arrangement of the masses is similar to the preceding figure but most of the individual masses have a more definite form. At the lower part of this nucleus is a chromatin mass (f) which shows two short heavy parallel strands directed centrally from the mass   Toward the center of the nucleus there is a large conspicuous chromatin mass which is evident in the succeeding Figures 3, 4 and 5 (chromosome a). There are fifteen well defined aggregates of chromatin and eight smaller diffuse masses which give a total of twenty-three in Figure 3. Figure 4 contains seventeen masses of chromatin which in the main do not reveal such a pronounced reticulum as in the preceding Figure 3. Fourteen chromatin masses are counted in Figure 5. These masses present a more filamentous

condition than any of the previous figures. These chromatin masses lie in close proximity to each other and are disposed for the most part to one side of the nucleus. The larger aggregates in this nucleus are similar to those of the previously mentioned figures.

Figure 6 is taken from a different cyst. This nucleus shows twelve masses of chromatin which are connected by relatively thick and dark staining strands. Some of these strands resemble thin, elongate, and ill formed chromosomes. At the lower part of the nucleus a large chromatin mass (g) is visible from which extend parallel projections directed centrally. Toward the center of the nucleus six rounded bodies of chromatin connected by strands are present.

In all the figures thus far cited there is a difference in the number, size, form, and relationship of the chromatin aggregates and strands. Some of these chromatin bodies found in different nuclei show marked similarities. See chromosome (a) in Figure 2 to 5 inclusive. Referring to Figures 1 to 6, it is apparent that some of the chromosomes are similar to the telophase chromosomes of the spermatogonia previously described—in that they are well defined, round bodies which are practically free from connecting strands, (Fig. 1, d and e). The other chromatin bodies present marked degrees of variation. Some have characteristic shapes and are well defined while others are diffuse. Most of the larger masses do not present the filamentous condition which is a common characteristic of the smaller and less defined chromatin aggregates. The strands vary in length and in thickness. Some are thin and attenuated while others are better defined and extend from the chromatin bodies in a more regular manner. The chromatin masses vary in respect to their position in the strand. Some of the chromatin bodies appear as thickenings in the middle portion of the strands while others occupy distal parts.

After the irregular and contorted chromosomal configuration of the stages previously described (Figs. 1 to 6) which correspond to the preleptotene stage, a series of transformations are seen. The changes at this time result in the formation of definite chromosomal filaments which are orientated in a definite manner, (Figs. 7 to 16, inclusive). This series of changes is characterized chiefly by the transformation of chromosome bodies which are not already synapsed into definite bivalent chromosomes by parasynaptic approximation. More-

over, another process is observed which involves an orientation of the bivalent filaments into an end to end association with each other. (Figs. 12 to 16 inclusive).

This arrangement of chromosomes results in the formation of a spireme in which each of the definite bivalent chromosomal constituents are clearly definable. The spireme is not continous in the sense that the morphological identity of the individual chromosomes is lost, but it is continous in that the ends of all the bivalent chromosomes are definitely associated with each other. This end to end approximation becomes conspicuous at the beginning of loop formation which may later form a bouquet.

Only a few of the total masses of chromatin are shown in Figures 7 and 8. From these masses extend rather uniform filaments which appear to have a more definite arrangement than was seen in the preceding figures, (Figs. 1 to 5). The thick and even chromatin filaments which are joined to each other are bivalent chromosomes. The other masses and strands are not so conspicuous.

The nucleus of Figure 9 reveals the chromatin exhibiting the most uniform behavior yet shown. In the lower portion of this nucleus, univalent chromosomes are pairing side to side. The chromatin of these filaments is evenly distributed throughout their length. In the upper left part of this nucleus (h) is a well defined bivalent chromosome. A chromosome is seen at the upper right part of this nucleus (i) from which extend two similarly disposed filaments.

Only a few chromosomes are shown in Figures 10 and 11. At the left in Figure 10, one bivalent chromosome (k) is seen which has formed a loop. Beneath this loop, there are two homologous chromosomes which are attached at their extremities thus forming a somewhat oval figure. Figure 11 shows two large diffuse and irregular masses from which protrude several filaments, two of which are well defined. Aside from these two filaments this nucleus shows evidence of poor fixation.

The are 13 bodies of chromatin in Figure 12. Ten of these bodies are joined by chromatin loops and filaments. At the lower part of this Figure, there are two parallel threads of chromatin which are joined at one extremity, the other ends are obscured by a V-shaped chromosome. A bivalent chromosome (l) is seen at the upper part of this figure. Chromosome (B) of this figure is one which is synapsed at its extremities

and some distance therefrom, while its central portions are free. This partially synapsed, loop-shaped chromosome, is joined with the bivalent loop to its right and with the univalent loop to its left by intervening bodies of chromatin.

The characteristic arrangement of the bivalent chromosome loops which have joined at their extremities is seen in Figures 13, 14 and 15. These chromosomes retain their individuality although they are joined end to end. This condition is well revealed in Figure 13, which shows only a few of the total number of chromosomes. The chromosomes of Figures 14 and 15 are for the most part synapsed, and in addition, the bivalent chromosomes are joined end to end. The condition of the chromatin at this time indicates that it is not completely condensed.

It is evident that in the behavior of the chromatin already described, the following processes are involved: (1) The synapsis of homologous chromosomes; (2) The orientation of the chromosomes into an end to end association; (3) The equalization in thickness and change in form of chromosomes into definite, uniform, and elongate chromosomes.

It is inferred that the above processes are influenced by the following factors: (1) The mutual attraction that synaptic mates have for each other; (2) The attraction that unlike chromosomes have for each other which results in the end to end association of unlike chromosomes; (3) The intrinsic chromatin changes which result in the formation of definite, uniform and elongate chromosomes; (4) The differences in relationship of the chromosomes as they emerge from the last spermatogonial telophase.

The first three of the above listed factors tend towards an uniformity in behavior of the chromatin while the fourth factor interferes with the simultaneous manifestation of the previously mentioned processes. By reference to Figures 7 and 8, paper No. 1, Baker and Rosof, 1927, it is seen that in the late spermatogonial prophase there are some homologous chromosomes which are paired while others reveal no close relationship whatsoever. This relationship of chromosomes influences the behavior of chromosomes as they emerge from the last spermatogonial telophase into the prophase of the primary spermatocyte in that they remain in this paired condition during the spermatogonial division and in the early prophase of the primary spermatocyte. This is indicated by the number,

size, form, and relationship of the chromatin aggregates and strands in the different nuclei.

It is inferred that the interval and mode of synapse is dependent upon the above listed processes. The chromosomes in this species do not all synapse in the same condition, nor do they synapse at the same time. Some of the homologous chromosomes become paired in the late spermatogonial prophase, as previously stated, while others give no evidence of synapse until the beginning of bouquet formation. Some of the homologous chromosomes come into close relationship with each other, and synapse during the time when the chromatin is filamentous, while other homologous chromosomes become synapsed during the clumped condition of the chromatin. If the chromosomes synapse while in the form of filaments, then the mode of synapse is unquestionably parasynaptic, Figure 9. There is some variation in respect to the parts of the attentuated homologous chromosomes that first become approximated during synapse. Some become approximated first, at their extremities, while others at varying places along the chromosome. On the other hand, if synapse occurs during the clumped condition of chromatin, it is impossible to determine with certainty whether or not the mode of conjugation is parasynaptic or telosynaptic.

Following the last stage described (Fig. 15), which concludes the leptotene stage, the most pronounced orientation of the chromosome loops occurs. This orientation may or may not result in the formation of a bouquet. In addition to this, the chromosomes which are not already bivalent and equalized in thickness throughout become so by the time this orientation is completed. Cells in this stage reveal the ends of most of the chromosome loops oriented toward the periphery of the nucleus, some being more peripherally oriented than others. This arrangement is accomplished by the shifting of the chromosome loops which are joined end to end.

There are eight well defined bivalent loops which are associated end to end and are peripherally arranged in Figure 16. At the left side of this nucleus in close proximity to the nuclear membrane, there are seen two elongate homologous components of a bivalent chromosome (c). These homologous elements are synapsed only at their upper extremity; the remaining parts are not synapsed but show a parallel arrangement. The lower extremity of the inner most univalent

chromosome of these homologous elements already occupies
an end to end relationship with a bivalent chromosome. The
upper extremity of these homologous chromosomes as previously
stated is synapsed, but in addition, this bivalent extremity also
occupies an end to end relationship with two bivalent chromo-
somes. In the center of the nucleus, at a lower level than the
majority of the chromosomes, a rather large and uneven chromo-
some is seen. This chromosome is thickened in its central
portion. At the same level and to the left of this chromosome,
there is a long and well defined chromosome (M) which has the
form of an incomplete figure eight. Its separated extremities
assume an end to end association with other chromosomes.
At the upper right portion of the nucleus, two distinct chromatin
bodies are seen. These bodies are nodules on the bivalent
filaments which extend from them.

This figure is significant in that it practically concludes the
processes which have been previously operating and marks a
change in the behavior of the chromatin. Previous to this
time, the processes involved are: (1) Synapses of homologous
chromosomes; (2) The end to end association of dissimilar
chromosomes; (3) The equalization in thickness and change
in form which result in definite, uniform, bivalent, and elongate
chromosomes.

Some chromosomes are seen in this figure which are not as
yet completely synapsed, and some that are not equalized in
thickness throughout. However, these are in the minority.
This Figure as well as Figure 12 also accentuates the fact that
the chromosomes do not all synapse in the same condition or
at the same time. Furthermore, the general arrangement of
the chromosomes in Figure 16 is indicative of the ensuing
chromosome behavior.

The figures succeeding the one just described show the
character of ensuing chromosomal behavior. At this time the
changes which result in the formation of pachytene chromosomes
may vary as follows: (1) Chromosomes may undergo complete
or partial bouquet formation, and then form pachytene chromo-
somes or, (2) the pachytene chromosomes may be formed
without undergoing a bouquet stage. Either of these two
methods may be interrupted by the intervention of the so-called
synezesis stage. This difference in the behavior of chromosomes
at this time as just mentioned has lead to considerable confusion
in the interpretation of the chromosomal changes in the primary
spermatocyte.

Figures 17 to 20 show imperfect bouquets. Ten loops having their ends directed toward a common area at the periphery of the nucleus are seen in Figure 17. Above these loops, two univalent loops whose ends are joined parasynaptically are visible. A comparison of the caliber of these partially synapsed univalent chromosomes with the bivalent loops in this nucleus shows a marked difference, the bivalent loops being much thicker. Furthermore, the general contour and disposition of the univalent loops differ from the bivalent loops in that the unsynapsed chromosomes indicate a serially arranged granular appearance which is not seen in the bivalent chromosomes.

Figure 18 is comparable to Figure 17. The chromosomes (a) of Figure 18 are two bivalent chromosomes which are joined end to end and simulate the partially synapsed univalent loops of Figure 17. However, these two similar configurations of chromosomes are easily discernible on account of their differences in thickness and contour. These two figures mark the last appearance of unsynapsed chromosomes.

A different phase of bouquet formation is seen in Figures 19 and 20. Here all the chromosomes are bivalent but they are not all oriented in the same manner. Both figures show twelve chromosomes, most of which are looped. The chromosomes which are not looped have their enlarged ends either directed centrally or come into contact with some part of a loop of another chromosome. Figure 20 shows clumped and twisted chromosomes disposed toward one side of the nucleus. This may be interpreted as a fixation effect.

The complete formation of a bouquet is seen in Figures 21 and 22. In this stage the chromosomes have their ends oriented toward a restricted area at the periphery of the nucleus. Eleven loops are visible in Figure 21. The full complement of chromosomes is not seen in Figure 22 due to the plane of section.

Figures 23 to 32 show the gradual contraction of chromosomes which results in the formation of pachytene chromosomes. During this process each bivalent chromosome exhibits an individuality of its own, and the changes which each chromosome undergoes can be followed with comparative ease if synezesis does not intervene.

The arrangement of chromosomes in Figures 23 to 27 varies considerably. All of these figures reveal chromosomes which are no longer joined to each other, however, the disposition of the chromosomes varies from that of an intermingled grouping

to that of a widely separated condition. The arrangement of the chromosomes in Figure 23 is highly suggestive of a continuity of the chromosomes, but close observation reveals an intermingled grouping of ten distinct chromosomes. Figure 24 shows eleven chromosomes that reveal their free ends oriented toward the periphery of the nucleus. These chromosomes are thicker than those of the bouquet. It may be inferred that this figure is a good illustration of chromosomes which have become disengaged from the bouquet orientation. Figures 25 and 26 show a slight massing of a few chromosomes. A slightly later stage is seen in Figures 27 and 28. These chromosomes are thicker than the previously described chromosomes and resemble more closely the pachytene stage. Twelve well defined chromosomes are present in Figure 28. At the right side of this figure a U-shaped chromosome is seen whose ends are attached to the extremities of a small V-shaped chromosome lying in a different plane. The relationship of these two chromosomes is the last occurrence observed of the process which involves the end to end association of dissimilar chromosomes which was previously described.

The chromosomes of Figures 29 to 32 inclusive are in the pachytene stage. The morphological individuality of each chromosome is marked in these figures. Each chromosome has assumed a characteristic form. This may be seen by reference to Figure 31 in which there are eleven chromosomes. Furthermore, the chromosomes are no longer clumped but are distributed throughout the cell.

Following the pachytene stage the chromosomes become elongated and thickened. The beginning of this process is shown in Figure 33. This condition is well shown in Figure 34. The chromosomes in this nucleus are partially coalesced and are less distinct. Figure 35 reveals the condition succeeding that shown in Figure 34. The chromosomes in the nucleus of Figure 35 are enlarged and diffuse and at the same time, individual chromosomes are again undergoing a process of shortening. The shortened chromosomes which result are still in a diffuse ·condition as is seen in Figure 36. This second contraction of chromosomes may be confused with synezesis unless the continuity of this process is followed through in close stages. It is difficult to discern the exact morphological characteristics of individual chromosomes at this time. This may be attributed to the difficulty in obtaining good fixation in this stage. These

chromosomes are resolved into the chromosomes of the diakinesis stage by a rearrangement and condensation of the chromatin.

The chromosomes of the diakinesis stage are characterized by their peculiar and constant shapes. Figures 37 and 38 show a gradual transition from the more diffuse condition of Figures 35 and 26 which results from the second contraction to the distinct and characteristic chromosomes of the diakinesis stage shown in Figures 39 to 41.

A typical nucleus in diakinesis is seen in Figure 40. Twelve chromosomes are present in this figure, seven of which are more peripherally arranged than the others. In the upper right portion of this nucleus four small chromosomes are visible. Below these, a large dumbbell shaped chromosome is seen. The remaining chromosomes are median sized. The great differences in size and form of the chromosomes facilitate their identification prior to, and succeeding diakinesis. Certain chromosomes in this stage are suggestive of tetrads, but close observations fail to reveal typical tetrads. Following diakinesis, the chromosomes continue to contract and change in shape until they become more or less rounded—Figures 42 to 46. At this time, the chromosomes are going on the spindle in preparation for the ensuing meiotic division. By reference to Figures 44 to 46, it is seen that the chromosomes become joined to each other by short, darkly staining chromatin strands. These cells give a count of twelve chromosomes. A polar view of the chromosomes on the spindle is seen in Figure 47. The resulting changes which now rapidly ensue are seen in Figures 48 to 54. These include the metaphase, anaphase, and telophase stages.

From an inspection of the above figures illustrating the stages it is seen that the behavior of the X chromosome is variable. In Figure 49 it is undivided and included with the main mass of chromosomes. In Figure 50, the X chromosome is undivided and proceeds towards the pole more rapidly than do the other chromosomes. The X chromosome has divided and occupies the poles of the spindle in Figure 51. In Figure 54, the X chromosome is undivided and lags behind the divided bodies of chromatin.

The dense, darkly staining and compact mass of chromatin which characterizes the synezesis stage has been omitted in the previous description and is seen in Figures 55, 56, and 57. There is a great variation in the type of synezesis exhibited by the various nuclei. Some of the nuclei in this condition show

chromatin loops or strands extending from the main mass, while other nuclei reveal the dark mass without any projecting elements. The loops and strands which project from the main chromatin mass vary considerably. Some are attentuated and irregular while others are thick. As has been previously mentioned the chromosomes may or may not undergo synezesis. It is our observation that chromosomes may undergo synezesis at any time following the end to end association of bivalent chromosomes, Figure 16 up to the pachytene stage, Figure 29. Without synezesis the behavior of chromosomes can be followed in an orderly fashion, but by the intervention of synezesis, it is difficult to follow with certainty the orderly sequence in the behavior of the chromosomes. From the study of this material it is inferred that synezesis indicates some change in the condition of the chromosomes, which renders the chromosomes susceptible to the action of the fixatives.

The transformations of the chromosomes following the end to end association which is seen in Figure 16 are summarized as follows: (1) Chromosomes may or may not undergo bouquet formation prior to the pachytene stage; (2) These two methods may be interrupted by the intervention of synezesis; (3) The pachytene stage follows and is characterized by the shortening of chromosomes which exhibits characteristic forms. These chromosomes are scattered throughout the nucleus; (4) Following the pachytene stage, the chromosomes elongate and thicken; (5) This stage is succeeded by a thicker, shorter and more diffuse type of chromosome; (6) Following this, the chromosomes undergo a second contraction and retain for a time their diffuse condition; (7) This is succeeded by the diakinesis stage. The chromosomes of this stage are no longer diffuse but again assume a characteristic shape; (8) The ensuing phase of development reveals the chromosomes in a contracted or rounded form. At this time, some of the chromosomes are joined to each other while going on the spindle preparatory to division; (9) Meiotic division now ensues.

The chromosomal transformations in Branchipus vernalis as described in this paper compare favorably with some exceptions to the table based on Winewarter's terminology as given in Figure 262 in "The Cell in Development and Heredity," by Wilson 1925, (third edition). A general consideration of maturation in this species will be reserved for the last of this series of papers.

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EXPLANATION OF PLATES.

PLATE I.

All Figures were drawn by aid of the camera lucida. Magnification of plate figures 1250 diameters. Comparisons are made as far as it is possible with the diagram, based on Winewarter's terminology in Wilson, "The Cell in Development and Heredity," Figure 262, (third edition). Figures 1 to 6 inclusive represent the preleptotene stage.

Fig. 1.   This nucleus shows 13 masses of chromatin which are for the most part connected by communicating strands. The arrangement of the strands is indefinite and the number of strands extending from the more conspicuous masses varies. The reticulum, characteristic of this early stage is effected by the separation of the chromosomes from the dense mass of the telophase plate of the last spermatogonial division. This figure corresponds favorably to the resting stage (Wilson).

Figs. 2 to 5.   These cells are from the same cyst. The number of chromatin masses is not constant in the various nuclei, but in no case do the masses exceed 23. The chromosome (a) is similar in form in these nuclei. The arrangement of the masses is similar to Fig. 1, but most of the masses have a definite and characteristic form. These figures correspond practically to the prochromosome stage.

Fig. 6.   This nucleus shows 12 chromatin masses. Some of the chromatin strands resemble thin, elongate and ill defined chromosomes. The apparent reticulum is less pronounced. The figure is comparable to the unraveling stage.

Figs. 7 to 16.   These nuclei reveal the most pronounced manifestation of the following processes: (a) Synapses of homologous chromosomes; (b) The orientation of dissimilar chromosomes into an end to end association; (c) The equalization in thickness and change in form of chromosomes into definite uniform and elongate chromosomes. These figures correspond to the leptotene stage.

Figs. 7 and 8,   show only a few of the total masses of chromatin. The thick and even chromatin filaments which are joined to each other are bivalent chromosomes. The other masses and strands are not so conspicuous.

Fig. 9.   The chromatin in this nucleus shows a uniform behavior. In the lower portion of the nucleus, the univalent chromosomes are pairing side by side. In the upper left portion, there is a well defined bivalent chromosome (h).

Fig. 10.   At the left, in this nucleus, one bivalent chromosome (k) is seen which has formed a loop. Beneath this loop there are two homologous chromosomes which are attached at their extremities and form a somewhat oval figure.

Fig. 11.   This nucleus shows two large, diffuse and irregular masses from which protrude several filaments. Two of these filaments are well defined. This nucleus shows evidence of poor fixation.

Fig. 12 shows 13 bodies of chromatin. Chromosome B of this figure is one which is synapsed at its extremities and some distance therefrom, while its central portions are free. This partially synapsed, loop-shaped chromosome is joined to a bivalent loop to the right and to a univalent loop to the left by intervening bodies of chromatin.

Figs. 13, 14, 15.   The characteristic arrangement of bivalent chromosomes which have conjugated at their extremities is seen in these figures. The chromosomes retain their individuality although they are joined end to end. The condition of the chromatin in this stage indicates a diffuse state.

Fig. 16.   This nucleus shows eight well defined bivalent loops which are associated end to end and are peripherally arranged. Chromosomes C shows two elongate and homologous components of a bivalent chromosome. These homologous elements are synapsed only at their upper extremity. The remaining parts are not synapsed but show a parallel arrangement. This figure is significant in that it marks a change in the behavior of chromatin, and may be interpreted as a transition stage between leptotene and post leptotene stages.
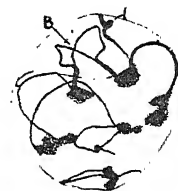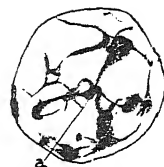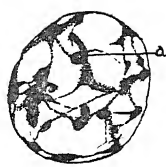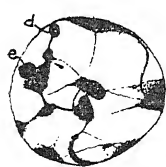
PLATE II.

Figs. 17 to 28 inclusive show the character of the chromosome behavior prior to the pachytene stage without the intervention of synezesis.

Figs. 17 to 20.   These nuclei show imperfect bouquets.

Fig. 17.   Above the loops, two univalent chromosomes are seen, the ends of which are joined parasynaptically.

Fig. 18.   Chromosome A of this figure represents two bivalent chromosomes which are joined end to end and simulate the partially synapsed univalent loops of Fig. 17.   It is inferred that Figures 17 and 18 may be stages prior to complete bouquet formation or that they may form pachytene chromosomes without undergoing bouquet formation.

Fig. 19 and 20.   These nuclei show a different type of bouquet formation. Here, the chromosomes are bivalent but they are not all arranged in the same manner.   Both figures show 12 chromosomes most of which are looped. The chromosomes which are not looped have their enlarged ends either directed centrally or come into contact with some part of a loop of another chromosome.   The following interpretations may be placed on these two figures.   (a) They may be stages just prior to complete bouquet formation.   (b) They may immediately succeed bouquet formation,   (c) They may form pachytene chromosomes without forming complete bouquets,   (d) These stages may mark the intervention of synezesis.

Figs. 21 and 22 show complete and typical bouquets.   Eleven bivalent loops are visible in Fig. 21, and only 8 loops visible in Fig. 22.   In no case are there more than 12 loops.

Figs. 23 to 29.   These nuclei show chromosomes following the conditions mentioned above and just prior to the pachytene stage.

Fig. 23.   The arrangement of chromosomes is highly suggestive of their continuity. Ten separate chromosomes are intermingled which suggests this continuous condition.

Fig. 24.   This nucleus shows 11 chromosomes that reveal their free ends oriented toward the periphery of the nucleus.   It may be inferred that this figure is a good illustration of chromosomes that have become disengaged from the bouquet orientation.

Figs. 25 and 26.   These nuclei show a slight massing of a few chromosomes.

Figs. 27 and 28.   These nuclei are in a later stage than any of the previous figures. These chromosomes are thicker than the previously described chromosomes and resemble more closely the pachytene stage.

Fig. 28 shows 12 well defined chromosomes.   At the right side of this figure a U-shaped chromosome is seen whose ends are attached to the extremities of a small V-shaped chromosome.

Fig. 29 to 32 inclusive show nuclei in the pachytene stage.   The total number of chromosomes is not present in these nuclei due to the plane of the section.   However, a count of chromosomes show that in no case does the chromosome number exceed twelve.

The morphological individuality of the chromosomes in these nuclei is marked.   Each chromosome has a characteristic form.   The chromosomes are no longer clumped but are distributed throughout the cell.

17.   18.   19.   20.
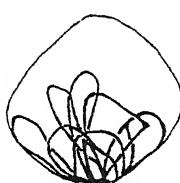
21.   22.   23.   24.
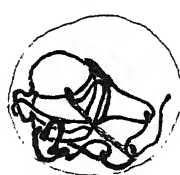
25.   26.   27.   28.

29.   30.   31.   32.

PLATE III.

Fig. 33.   This nucleus contains 12 chromosomes, some of which are elongating and thickening.

Fig. 34.   The chromosomes in this nucleus are elongated and thickened. Some of the chromosomes are partially coalesced and are less distinct.

Fig. 35.   The chromosomes in this stage are thickened, enlarged and diffuse, but at the same time the individual chromosomes are again undergoing a process of shortening. This corresponds to the diffuse stage.

Fig. 36.   The chromosomes in this nucleus are shortened and are still in a diffuse condition. This second contraction of chromosomes may be confused with synezesis unless close stages are followed. This corresponds to the second contraction stage.

Figs. 37 and 38.   These two nuclei show a gradual transition from the more diffuse condition resulting from the second contraction to the distinct and characteristic chromosomes of the diakinesis stage.

Figs. 39 to 41.   These nuclei show characteristic chromosomes of the diakinesis stage.

Figs. 42 to 46 show the condition of chromosomes following diakinesis. The chromosomes at this time continue to contract and change in shape until they become more or less rounded. In Figures 42 and 43 the nuclear membrane is present. The nuclear membrane has disappeared in Figures 44, 45, 46. The chromosomes of these nuclei become joined to each other by short and darkly staining chromatin strands. These cells give a count of 12 chromosomes. In some of these figures, the centrosomes are visible.

Fig. 47.   This figure is a polar view of the chromosomes on the spindle. In this figure as well as in the succeeding figures the accessory chromosome is indicated by the letter X.

Fig. 48.   A profile view of a spindle.

Fig. 49.   Metaphase.

33.   34.   35.   36

37.   38.   39.   40.

41   42.   43.   44.
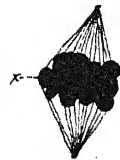
45.   46.   47.   48.   49.
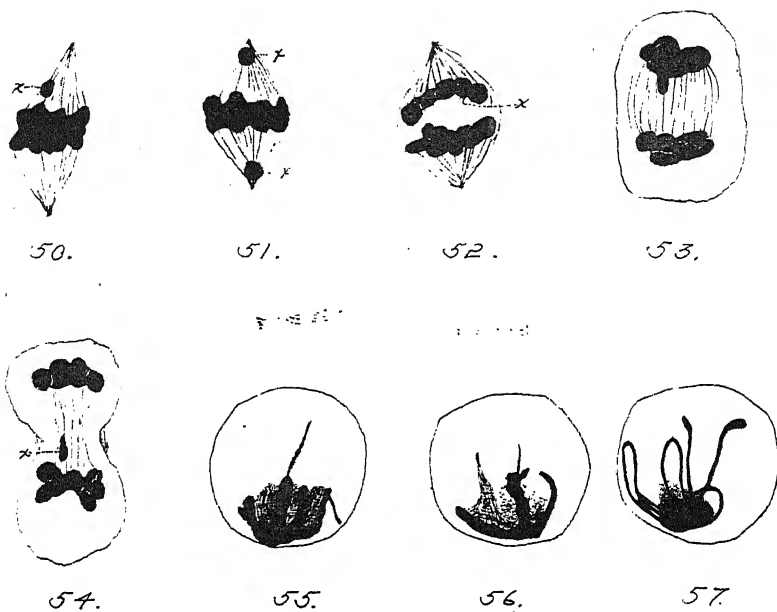
PLATE IV.

Fig. 50. A metaphase showing the undivided accessory chromosome proceeding in advance of the main mass of chromatin.

Fig. 51. The divided X chromosome occupies the poles of the spindle.

Fig. 52. Early anaphase. The X chromosome is undivided and is proceeding toward the pole with the main mass of chromatin.

Fig. 53. Late anaphase.

Fig. 54. Telophase showing the X chromosome undivided and lagging behind the divided bodies of chromatin.

Figs. 55, 56, and 57. These nuclei are in synezesis. These figures were placed at the end of the series because without synezesis the behavior of chromatin can be followed in an orderly fashion, but with the intervention of synezesis it is difficult to follow with certainty the orderly sequence. The chromosomes may undergo synezesis at any time following the end to end association of bivalent chromosomes up to the pachytene stage. The chromatin in these figures is disposed to one side of the nucleus and is arranged in a dense, darkly staining and compact mass.

Fig. 55. This nucleus shows two filaments which extend from the synezesis mass.

Fig. 56. Several irregular strands extend from the synezesis mass in this nucleus. These synezesis masses resemble closely contracted bouquets.

Fig. 57. Three distinct loops and two pronounced and elongate chromosomes are seen extending from the synezesis mass.

PRINCIPLES OF PLANT TAXONOMY, V.*

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After studying the taxonomy of plants for twenty-five years the very remarkable fact became evident that there is no general correspondence of the taxonomic system with the environment, but as the great paleontologist, Williams, said in 1895: "environmental conditions are but the medium through which organic evolution has been determinately ploughing its way." Of course, the very fact that there is a system of phylogenetic relationships of classes, orders, families, and genera and that these commonly have no general correspondence to environment shows that, in classifying the plant material, we must discard all notions of teleological, utilitarian, and selective factors as causative agents of evolution.

The general progressive movement has been carried on along quite definite lines. The broader and more fundamental changes appeared first and are practically constant, and on top of these, potentialities or properties of smaller and smaller value have been introduced, until at the end new factors of little general importance alone are evolved. These small potentialities are commonly much less stable than the more fundamental ones and thus great variability in subordinate characters is often present in the highest groups. We must then think of the highest groups as being full of hereditary potentialities while the lower groups have comparatively few.

As stated above, there is a profound non-correspondence of the taxonomic system and the various orthogenetic series with the environment. The system of plants, from the taxonomic point of view, is non-utilitarian. The abundant adaptations of details to environment have no direct relation to the taxonomic

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*Papers from the Department of Botany, The Ohio State University, No. 214.

system and do not run parallel with it.   The same progressions take place whether a group is moving into the water or is remaining in the aerial environment.   It is also self-evident that the most diverse taxonomic groups are adapted to and thrive in the same general environment.   If there is, here and there, a correspondence, it is a mere coincidence, sometimes necessary for survival and sometimes not.   Ecological adaptations, however, also appear in large groups of plants, as in the cacti and certain spurges, which fit well into a desert habitat although there is little similarity in their special fundamental morphology when compared with each other.

THE DETERMINATION OF LOWER AND HIGHER LEVELS IN THE SERIES.

In any series, the high types can be distinguished from the low because the low have a less complex heredity and a less complex reaction system when compared with the higher types. The relative position can also be readily determined by considering the degree of divergence of two or more types of homologous organs of the individual, as by comparing the floral axes and their peduncles and the inflorescence axes with the vegetative axes; or comparing sporophylls with foliage leaves. In a primitive lycopod or an araucarian the floral axis is very little different from a vegetative axis; in a *Magnolia* there is an appreciable difference; while in a poplar or sunflower the difference is enormous.   The same comparisons would hold true for the sporophylls and foliage leaves in these types. Often a progressive series extends for a great distance from low to high forms, giving unmistakable criteria for judging the relative degree of advancement of any species or group; as, for example, the progressive development of a more definite and prompt determination of the floral axis in the case of strobili and higher flowers.   In finding comparative levels, the sporophylls are often of great value.   In the lowest levels there is no essential difference between the characters of these organs and the foliage leaves, except that the former bear sporangia, as in many lower Polypodiaceæ; while on a higher level, as in *Onoclea* and *Pteretis*, *Equisetum arvense*, or *Lycopodium complanatum*, the angle of divergence is comparatively great; although not nearly so great as in an angiosperm.   One can also compare the diversity and divergence of vegetative branches to determine comparative levels in the progressive series; as,

for example the simple branching system of *Lycopodium luci-dulum* with the polymorphic branches of *Lycopodium com-planatum*. A progressive series is evident when one compares *Lycopodium annotinum* without inflorescence with *Lycopodium clavatum* and with *Lycopodium complanatum*. The evolutionary advancement is evident at a glance. A similar more extensive movement of inflorescence developments is shown in the gymnosperm series: *Araucaria imbricata, Cunninghamia sinensis, Cryptomeria japonica, Taxodium distichum, Ephedia trifurca.* One can find similar progressive series in a large number of monocotyl and dicotyl groups. If we compare the flowers and clusters of *Araucaria bidwillii, Magnolia foetida, Prunus ameri-cana, Salix amygdaloides,* and *Leontodon taraxacum,* we can easily see that the order given represents a very decided series of evolutionary advancement, and a correct presentation of their relative positions as high and low, when compared with each other without any reference as to their direct relationships. The order given represents the proper sequence of higher and more complex hereditary natures in respect to the structures under consideration. The same sequence would be indicated if in each case we would compare the degree of divergence between the sporophylls and foliage leaves. The difference in character between the floral axis and its peduncle and an ordinary vegetative axis will also indicate comparative levels very well. The difference in *Araucaria imbricata* is very slight, in *Magnolia foetida* not very pronounced, while in such an extreme form like *Populus deltoides* it is very great. This means then that the *Populus* cell has a highly complex heredity which in one case can bring out a thick woody vegetative stem and in the other a delicate, thread-like herbaceous stem repre-sented by the pedicel and inflorescence axis. Any one can understand the implication when he remembers that in the most primitive vascular plants, like a *Lycopodium lucidulum* or a simple fern, all the branches are exactly alike in their hereditary expression. Such estimations of the degree of divergence of homologous structures in the individual are in general a correct measure of relative position. A *Lycopodium lucidulum, Mag-nolia,* and *Populus* would receive exactly similar treatment if their relative positions were judged by the degree of determi-nation expressed in their reproductive or floral axes. A large number of such progressive differences can usually be discovered and it must always be remembered that it is the summation

of all the fundamentally important evolutionary processes which determines the relative position of a plant in the absolute scale. A plant is sometimes very advanced in one character and quite retarded in another.

In plants with flowers, the degree of promptness of determination of the reproductive axis usually gives very definite evidence of relative position in the progressive scale as indicated by the following examples: Staminate cone of Strobilophyta,—*Araucaria brasiliensis*, 1000 ± stamens; *Araucaria excelsa*, 400 ± *Pinus strobus* 200 ± ; *Podocarpus spicata*, 70 ± ; *Taxus canadensis* 7 ± ; *Ephedra trifurca*, 5; *Gnetum latifolium*, 1. Monocotyl hypogynous series, Alismatales,—*Echinodorus cordifolius, Alisma subcordatum, Tenagocharis latifolia, Triglochin maritina, Triglochin palustris, Scheuchzeria palustris, Potamogeton natans, Althenia cylindrica, Naias flexilis, Zostera marina.* An hypogynous dicotyl series,—*Magnolia foetida, Ranunculus septentrionalis, Caltha palustris, Geranium maculatum, Agrostemma githago, Claytonia virginica, Anychia canadensis, Corispermum hyssopifolium, Monolepis nuttalliana.* An epigynous dicotyl series,—*Philadelphus coronarius, Nuttallia decapetala, Mentzelia oligosperma, Chamaenerion angustifolium, Ludwegia sphaerocarpa, Circaea lutetiana, Hippuris vulgaris.* All these lines and many others show the same remarkable orthogenetic series which is plainly the result of a continuously more prompt determination of the floral axis. This movement is even evident to some extent in the strobili of the Lepidophyta and Calamophyta. Such movements show no correspondence with the environment and all teleological explanations as selective value, interaction with the environment, or use and disuse have no scientific meaning, but belong to the childhood stage of biology. Correct ideas in regard to the evolutionary process are of the greatest importance in arriving at a proper phyletic taxonomy.

In the vegetative system there is a progressive movement in complexity of the branching system from the completely unbranched to a very extreme system and then a specialization from a moderately branched system to a comparatively simple condition, usually with the development of herbaceousness, and a progressive development of vegetative determination in some or all of the terminal buds of the plant. Commonly there are closely related woody and herbaceous forms in the same group, and larger groups are not to be segregated, merely on the basis

of woodiness and herbaceousness. These characters for the most part merely represent levels which are attained in a multitude of cases.

Although the secondary sexual condition is not manifest in the sporophyte until the heterosporous pteridophyte stage and the bisporangiate flower is carried through to the very highest group of dicotyls, nevertheless there is, all along the line, a progressive movement in very many branches from this condition to complete dieciousness. The movement is from sex determination at the end of the sporophyte ontogeny to earlier and earlier stages of the ontogeny until the limit is reached in the egg. The four general steps in this progression are: first, male and female determination on the same sporophyll; second, bisporangiate flowers, in the angiosperms with stamens below and carpels above; third, the various types and degrees of moneciousness; and fourth, the complete diecious condition which is, however, also developed in various degrees of completeness and intensity. There are exactly similar progressive movements in the gametophytes of the Homosporous Metathallophyta.

Progressive levels of complexity are also indicated by the diversity of leaf forms. In the lowest vascular plants like ferns and lycopods, there are but two types of leaves, foliage leaves and sporophylls, with practically no vegetative difference between the two. With the introduction of heterospory, there are at least three kinds of leaves. In cycads there are four kinds, in the lower Araucarians there are but three general kinds of leaves, while in *Pseudotsuga* there is a general tetramorphous condition. In the extreme Pinaceae, as in *Pinus*, there are beside the special juvenile leaves, two kinds of sporophylls one kind of foliage leaves, one kind of scale leaves on the dwarf branches, and two kinds of scale leaves on the ordinary branches. In some species these various categories will divide up into further subordinate types. In the gymnosperms the condition of the cotyledons follows along in the same general sequence. The lower gymnosperms have two cotyledons normally, while the number rises rapidly in the Pinaceæ until it reaches a dozen or so in some pines. The development of specializations in the embryo is even more remarkable and attains its extreme expression in the bizarre embryogeny of the pines and certain of the Juniperaceæ. Thus these parallel movements in the development of complexity of the hereditary

potentialities are correct criteria for judging the relative positions of the forms to be classified as high and low. Now it is true that occasionally a group may have retained with little or no change some very primitive structures in some part of its anatomy. Such a condition can, however, not be used to pull a species or group down to the lower level. Because a man may have retained the potentiality to produce gill-slits, either in the embryonic stage or up to the mature condition, does not put him on the level of a fish. The complexity of the hereditary potentialities as a whole will give the proper basis for a correct determination of any given case.

In the smaller branches of the phyletic system there are often quite definite orthogenetic movements resulting in definite orthogenetic series. In such cases the arrangements are to correspond to these movements. The sequence from low to high, from simple to complex, will then be properly indicated by the classification. Usually we cannot tell the actual sequence of origin of one form from another in such an orthogenetic series unless paleontological evidence is available. But the fact of the existence of an orthogenetic series is more important than speculations about its causes or the order of derivation of the members of the series.

The Definite Limits of Various Orthogenetic Series

It is evident, both from a consideration of various fossil groups and from a study of taxonomic series of living species, that many evolutionary movements come to a definite limit or end, beyond which no further advance is possible. In fact, practically all of the major movements are of this nature. The evolution of the time of sex determination proceeds backward through the ontogenetic cycle until it has progressed through both the gametophyte and sporophyte where the limit is reached in the diecious condition, when the circle is completed. The development of the flower progresses from the very slow determination of the primitive strobili until the highest stage is reached in the epigynous flowers in which the central growth of the flower axis stops before any floral parts have even made their appearance as incepts. In some of the higher Andropogoneæ a curious box is developed containing the grain. This box becomes more and more perfect until the extreme is reached in teosinte. In the Liliales the most primitive species are large trees, and many of the lines progress by successive steps

to smaller herbaceous forms, with the vegetative stem finally completely underground and only a few millimeters in height, all of the leaves and the flower clusters coming from below the surface. The dropping of stamens and other parts through the evolution of zygomorphy proceeds in the same way. Everywhere at the extreme limits, the flower has by successive stages arrived at the condition where only two or one stamen are left. The limit of development of the syncarpous gynecium is a unilocular ovulary with two stigmas or only one. The progressive limit in the relationship of sporophyte to gametophyte is the seed plant condition where the gametophyte is parasitic in the sporophyte and the sporophyte embryo is parasitic in the gametophyte. The recognition of these limits is of very great importance in taxonomic studies. Not only do the higher types approach evolutionary limits but in some cases "over adaptation" is brought about. The structure is carried far beyond the limits of practical utility, as for example, the parachute development in the fruit of the dandelion and others of the same family. The highly evolved plant is full of hereditary potentialities and thus often has enormous possibilities for minute variations when compared with the lower forms. The lower form has more of the primary heredity and usually little of the superficial while the higher contains all the primary properties and in addition a host of superficial and insignificant factors. These superficial factors are commonly transcient or mutable, hence in many such high forms mutations are continually appearing. On the other hand some limits become remarkably stable.

Extraordinary Developments Appearing at the Ends of Extreme Phyletic Branches.

From what has been said in the preceding paragraph, it is evident that many extraordinary bizarre, and extreme developments will commonly be found at or near the evolutionary limits. Among such peculiar systems, the following are noteworthy: In *Azolla* the microsporangium develops a number of massulæ containing the spores and on the surface of these massulæ numerous anchor-like processes or glochidia are present. The higher Selaginellas present a very peculiar stem structure. There are tubular air cavities and the vascular bundles extend through the center of the tubes and are connected with the

ground tissue by means of filaments of cells or trabeculæ passing across from the outside of the bundle to the wall of the air cavity. In the higher Pinales there is a remarkable system of multiple embryos with unusual suspensors as well as an extreme development of the number of cotyledons. In the *Pinus* embryogeny and also in *Biota*, we have a type of embryo development which is not duplicated in any other vascular phylum. In the Gnetales, the leaves of *Tumboa* present an extreme and peculiar system. The only two foliage leaves that the plant produces continue to grow from the base as long as the plant lives until they are ribbons, yards in length. The beginning of such a leaf development is also present in Pinus which belongs to the same phylum. But in even the most extreme cases of this character in *Pinus*, the basal growth continues for but a comparatively short period and the needles rarely reach a length of two feet. In the higher Helobiæ, *Vallisneria* has developed a remarkable method of pollination in that the minute submerged staminate flowers are separated from the inflorescence to float on the surface, where they come in contact with the stigmas of the capellate flowers, which have been brought to the surface on an enormously long, spirally coiled peduncle. In the region of the highest grasses are the Indian corn (*Zea*) with its extraordinary stigmas, ear, and husks, and teosinte (*Euchlaena*) with its caryopsis packed up in a wonderfully constructed "alabaster" box, as recounted above, along with elongated stigmas and husks much like in its near relative. In the highest monocotyls, the orchids, one finds a host of remarkable developments, in the pollen masses, bizarre perianths, and often exceedingly peculiar leaf structures. Near the top of the Thalamifloræ are the violets, the highest of which present us with the problem of showy and cleistogamous flowers to the confounding of both Lamarckian utilitarians and Darwinian selectionists. These cleistogamous flowers as well as parthenogenetic developments of various types appear in the higher regions of many subordinate phyla. In the extreme Piperales we meet with 16-celled female gametophytes with their remarkable developments of multiple nuclear fusions, in one species of *Peperonia* the definitive nucleus being formed by the fusion of 14 polar nuclei. In the specialized Amentiferæ, as in *Casuarina, Ulmus*, etc. chalazogamy has developed, representing the extreme condition of the evolution of the parasitic ability of the pollen tube. At the end of the Gentia-

nales stand the Milkweeds with extreme pollen specialization in
evidence, again simulating the development in *Azolla* and the
orchids.   The method of pollination evolved in our common
species, *Asclepias syriaca* is so efficient that with an ideal
environment, with an abundance of insect visitors at hand, a
milkweed flower has one chance in about 80 of being pollinated
and thus contributing its service in the perpetuation of its race.
The mints stand at the top of their order and the salvias at
the top of the mints in progressive specialization of the flower.
Now in the extreme species of *Salvia* two fertile half stamens
are present in the flower which are so developed that they
form a perfect brush and lever arrangement for spreading the
pollen on an insect's back.   This apparatus is one of the most
remarkable in the plant kingdom, and the lucky *Salvia* would
certainly be envied by its unlucky relative, *Asclepias*, if plants
were able to experience envy at the good fortune of their
neighbors.   Near the top of the Scrophulariales stand the
Bladderworts not only with highly evolved flowers but with
their remarkable bladders or aquatic traps.   Without multi-
plying examples further this list can be completed by a reference
to the dandelion (*Leontodon taraxacum*) which stands about
at the top of the plant kingdom.   This plant has developed
a type of parthenogenesis through the aquisition of some heredi-
tary potentiality which interfers with the proper primary
sexualization of its synaptic chromosomes; yet we all know how
rarely a dandelion flower fails to set seed.   Along with many of
its relatives, the dandelion has evolved a peculiar, elongated
neck at the top of its fruit which together with the pappus
(which in itself is a remarkable structure at the end of calyx
evolution) forms a most efficient parachute.   Thus the dande-
lion, which has such a severe struggle to maintain itself in our
front lawns and roadsides is able to send its offspring a hundred
miles or so away from the paternal home where another favorable
lawn or roadside may be available in which the child may
possibly survive in a cruel and untoward world!
     Now the recognition of these special developments is one of
the most important exercises in taxonomy, because the more
primitive members of any main or subordinate phylum rarely
show extreme specializations except perhaps in very unimportant
details.   Curiously enough some of the conditions listed above
have in the past been regarded as indicating primitive conditions,
as the presence of chalazogamy in *Casuarina*, the extremely

advanced floral structures of Taxales, the multiple embryony and multiple cotyledons of Pinales, and the highly complex condition of *Zea* and its relatives. In fact there are yet few plant taxonomists that do not still place Zea at the base of the grass series. According to such a scheme, Indian corn must have been a special creation, without father, without mother, including all specializations and complexities, which after its placement on the earth gave rise to the series of lower and lower and more simple forms by devolution, each main step taken in the family leading nearer to the simple starting point of the lowest vascular plants. It is truly remarkable that such crudity of scientific concepts could be perpetuated until the present day and still be followed as the authoritative and orthodox faith of most of the taxonomists the world over. The older taxonomies, based on the old crude morphological conceptions and the teleological explanations of Lamarck and Darwin of the causes of evolution, as well as some of the newer systems which have not been emancipated from these notions, are so far from the reality that one actually finds that an entirely new beginning must be made if taxonomy is to be, as it should be, a systematization of our knowledge of the evolution of plants and a picture of the actual relationships. The new patch cannot be put on the old garment. The old bottles will not hold the new wine.

Distinguishing Phyletic Segregative Characters.

To distinguish fundamental segregative characters from progressive or merely detailed specializations is one of the main difficulties in taxonomy. As soon as one has advanced but a short distance in systematic botany, he is able to tell at a glance almost any of the thousands of members of such great families as, the sedges, grasses, orchids, legumes, mints, or composits. It must thus be that through all the multitudinous mutations which have resulted in subfamilies, tribes, genera, subgenera, species, and varieties something has remained which has not changed at all or only to such a slight degree that it is still recognizable. One of the chief exercises in phyletic taxonomy, therefore, is to ascertain these fundamental potentialities and characters, which because of their inherent stability give us our taxonomic system.

INDEPENDENCE OF THE VARIOUS MUTATIVE MOVEMENTS.

Although there is more or less parallelism in all movements going on in a phyletic line in a general way yet one series of possible advances may remain stationary while another advances rapidly even to the extreme limits. Thus it often happens that primitive and advanced characters appear side by side in the same species or group. This fact causes much confusion. There are also important progressive movements which originate in independent phyla at very diverse levels and in very diverse biological systems, in diverse environmental conditions. The origin of the flower or determinate reproductive shoot is of this nature. It appears in the homosporous level in two phyla while there are heterosporous pteridophytes which are entirely indeterminate, and among the gymnosperms, although a strobilus is mostly present in the living species, yet *Ginkgo* has come to a high evolutionary level with no determinate axes whatever.

PARALLELISM.

The parallel developments of both large and small degree are a constant source of uncertainity in taxonomy. Duplicate evolutions in different phyletic series are to be found in enormous numbers and frequently give rise to striking mimicries which have played such a prominent part in teleological explanations. But unfortunately for these crude utilitarian hypotheses, the duplications commonly occur without any relation to time or place, and even without similarity of ecological conditions. The older conceptions of selective mimicry belong to the same category as children's fairy tales, witch stories, and mother goose prodigies.

Parallelism necessitates distinguishing between characters that are segregative in kind, and characters which are merely corresponding stages in an orthogenetic series. For example, Orchidaceæ, Hydrocharitaceæ, Onagraceæ, and Campanulaceæ all have characteristically epigynous flowers, but the epigynous character which they have in common does not at all indicate relationship, but merely similarity of phylogenetic level. In the past, and to a large extent even in the taxonomic systems in vogue at the present time, such conditions are supposed to indicate relationship, as the character of the corolla, which is used to divide Dicotyls into apetalæ, choripetalæ, and sympetalæ, the apetalous forms being assumed to be primitive; but

one can find apetalous groups even among the Compositales. These three characters result from the progressive shortening of the floral axis, the choripetalous condition being the most primitive and the sympetalous and apetalous conditions more advanced stages due to earlier determination. In contrast to such characters that only indicate similar orthogenetic levels, true segregative characters are indicated in the fundamental branching systems of Lepidophyta and Ptenophyta. The first have dichotomous branching and the second monopodial branching. Such a difference is a true phyletic segregative difference between the two phyla, because the branching is brought about in a fundamentally different way in the two cases and the one is not higher than the other nor a derivitive from the other but only a different way of accomplishing the same thing, namely, an increase in the number of growing buds and axes. Each system may and does evolute from an exceedingly simple branching system to a very complex one.

RECAPITULATIONS.

The partial or complete suppression of hereditary characters through the addition of new ones is of great interest to the taxonomist. For if such characters can be expressed for only a short period either as a normal process in the ontogenetic cycle or through the influence of some unusual environment which permits the suppressed potentialities to come into play, important evidence of obscure relationship may be obtained. The recapitulation may occur in the embryonic or juvenile phase of development, in a certain period of the mature ontogeny, or at the very end of the ontogenetic cycle. Many cases of undoubted recapitulations in the juvenile phase are known, as in some Acacias with phyllodes in the mature condition. The juvenile form regularly develops several, typical, compound leaves of the *Acacia* type. Recapitulation is seen at the end of the ontogenetic cycle in many flowers. In the grasses the vegetative phase develops a two-ranked leaf condition, but the ultimate floral axis invariably returns to the primitive three-spiral condition. In *Cabomba*, dissected leaves appear on the growing plant but at the very end, before the flowers appear, several minute vestigial, peltate leaves usually develop to proclaim its relationship to *Brasenia* and *Nelumbo*. In *Equisetum*, the leaves are degenerate and form a united sheath but the sporophylls appear as distinct structures, which is plainly a return to the condition of the *Equisetum* ancestors

with normally distinct leaves.   In some plants recapitulations
can be brought about by merely disturbing the normal func-
tional gradients.   In hemp, the several rejuvenations which
can be brought about are always follwed by the appearance
of simple leaves, in the first stage of the new growth cycle in
the same way as when the plant is developing from the seed.
On the other hand, just as supressed heredity may normally
show only in the determinate, senile condition of the ontogeny
so new heredity may be added to modify the character of the
embryo or the juvenile phase.   The embryo is subject to the
same kinds of phylogenetic changes as the mature plant.
Past opinion to the contrary has sometimes resulted in decidedly
incorrect speculations as to relationships based on superficial
similarities or dissimilarities of the embryos.   But recapitula-
tion when carefully considered is often an important aid in
determining correct relationships.   Recapitulation is made
possible by the fact that most of the important new heredity
is laid down on the old and may supress the activity of the old
or limit its activity to a special phase of the ontogenetic gradient.
In some cases important new heredity may not show until
near the end of a determinate gradient, as in the spikelets of
Cyperus which have two-ranked glumes and flowers while the
vegetative phase of the plant continues in the more primitive
3-spiral condition.

TRANSFORMED ORGANS.

How are we to conceive of the significance of a change in
organs when, for example, the blade of a *Botrychium* develops
one or more sporangia, which normally appear only on the stalk
of the special sporangiophore?   In the past morphology much
speculation was based on such abnormalites since the plant
was usually thought of as being built up of a certain number of
homologous and diverse parts, just as a house is built up of
boards, bricks, stones, etc.   In the case cited the abnormality
would have no more significance than that the functional
gradient was disturbed through one cause or another and the
cells brought into the condition where reproductive sporangium
factors are brought into play.   If the leaf normally present on
a tulip peduncle is partly or completely transformed into a
petal-like structure, it does not mean that the tulip formerly
had petals where it now has leaves but merely that the functional
gradient in the given peduncle arrived a little earlier at the
condition in which petal factors normally come into play.

By disturbing the functional conditions in hemp it is easy to throw the sex of the carpellate plants to maleness in some branches and of the staminate plants to femaleness. In such cases it happens quite frequently that stamens appear with well-developed stigmas projecting from their tips. This does not mean that the ancestors of the hemp had stamens with stigmas. On the transition from vegetative to flower expression in a grass the two flowering glumes are developed, the lemma with a central midrib and the palet with two ribs. This does not mean that the palet represents two ancestral leaves or even sepals but simply that in the present system the floral axis is so shortened that the lateral organs appearing on the transition zone between the two-step to the three-step expression, partake of both conditions because the one set of factors has not become quiescent before the other is becoming active.

INTERPRETATION OF VESTIGES IN THE FLOWER.

Vestiges may appear in the flower due to vegetative reduction. Frequently the sporophylls at the tip of the cone are vestigial because the factors of determination come into play before the structures have had time to reach full development, as is to be seen prominently in *Equisetum* cones and in the carpellate cones of *Pinus*. Structures reduced through one cause or another may also assume special characters as the reduced glands or vestiges in the lower part of the andrecium of *Geranium*, *Pelargonium*, *Oxalis*, and *Linum*. The most prolific source of vestigial sporophylls in the flower is caused by displacement of the time of sex-determination. Since the primitive Angiosperm flower is bisporangiate with the secondary male state in the lower part of the axis and the secondary female state above, it follows that when the sex is determined somewhere below the flower, the given sexual state will then inhibit the development, to a greater or less degree, of the opposite type of sporophylls. A female state in the entire flower will interfere with normal stamen development and a male state will interfere with normal carpel development. Generally speaking, if the change is present in a low type of Angiosperm flower the vestiges will be large while in a high type they are frequently absent entirely. In some cases the stamen vestiges may be present and the carpels entirely suppressed, while in others the carpel vestiges may be present and the stamens completely suppressed. These vestiges, due to displacement of the time of sex determination, are commonly

of great importance in showing relationships, or lower and higher evolutionary levels. In some cases of moneciousness or dieciousness, the flowers in one sexual state are on a much lower evolutionary level than those in the other sexual state, and these conditions may be of service in determining relationships. Of course, the complete suppression of the opposite set of organs in one flower and not in the other, as mentioned above, would come into this category. Very extreme cases are represented by *Cycas*, *Hydrocharis*, and *Cocos*. In *Cycas* the carpellate plant is a flowerless plant having an indeterminate reproductive axis, while the staminate plant is a flowering plant with definite, determinate staminate axes, or cones. In *Hydrocharis* the staminate flower is hypogynous with more numerous sporophylls and apocarpous carpel vestiges while the carpellate flower is completely epigynous with a syncarpous gynecium. In *Cocos* the staminate flowers have a nearly completely apocarpous andrecium of three vestigial carpels while the carpellate flower has a completely syncarpous gynecium. A common source of vestiges is found in the telescoping of vegetative and reproductive expressions associated with the progressive contraction of the floral axis. These vestiges are abundant at the base of the angiosperm flower as, for example, in the six or fewer perianth bristles of *Scirpus* and *Eleacharis*. Such imperfect developments of a less extreme type are prominent at the base of the carpellate cones in the higher species of *Pinus*.

HYBRIDIZATION IN EXTREME GROUPS.

In some of the more extreme genera, there is not only much mutation but the functional and morphological conditions are such that there is no barrier to free hybridization. This results in an almost endless multiplication of combinations and of frequent irregularities as well. The group of species or even the single species appears to break up into a fine spray of forms and combinations of characters. Such genera are represented by *Crataegus*, *Oenothera*, *Rosa*, *Salix*, *Hieracium*, *Zea*, etc. These complexes of species and varieties have been the despair of systematists as well as the seducers of the philosophically inclined geneticists and evolutionists, who have seen in such extreme conditions the very basis of evolutionary activity and genetic foundations. Evidently a special treatment of such genera and species would be desirable since they do not fit very well into the straight jacket of ordinary taxonomic procedure.

CLASSIFICATION AND CHROMOSOMES.

Larger and smaller groups commonly have a base number of chromosomes with haploid and diploid complements because of the processes of fertilization and reduction. So long as the number of chromosomes is similar there is no mechanical difficulty in perpetuating the results of a hybridization. But if the haploid complements are unequal in number, irregularities are the inevitable result, because in synapsis it is impossible to have a complete mating even though no incompatibility to pairing of chromosomes is present. The cytological study of a complex species or group of species is thus of great practical value. On the other hand, the mere shifting of chromosomes or the multiplication of the base number is of no fundamental taxonomic or evolutionary importance, although such mutation has probably been going on from the beginning of sexuality. Normally a proper balance is attained with efficient survivial value, and the same base number may be commonly present in a wide diversity of related forms. The real evolution of plants which has resulted in the taxonomic system was through the addition of new potentialities in the structure of the protoplasm itself, presumably mainly in the structure of the chromosomes. The mere multiplication of the base number of chromosomes from the primary haploid and diploid normal to a triploid, tetraploid, or even greater polyploid number has little or no effect on the process of speciation, to say nothing of the great fundamental progressive and segregative processes which brought about the taxonomic system. Miss Blackburn has recently shown that a 16-ploid race of *Silene ciliata* can hardly be distinguished from a tetraploid race. The mere accumulation of chromosomes of like potentialities has no bearing on the evolution of new potentialities. It is the assimilative potentiality of the chromosome that must be changed. If such mutative changes have gone on or are continuing and no incompatibility exists to interfere with the primary sexual processes of either the normal union of the gametes or the synapsis of the chromosomes then hybridization with diverse mixtures of chromosomes may give rise to many new combinations with favorable selective value, resulting in diverse combination varieties, which would otherwise probably never come into existence. The supposed speeding up of mutations reported from the irradiation of certain plants and animals, although they may actually show a specific effect, which is

not at all certain since unfortunately the experiments have so far been tried only on the extremely complex species of *Drosophila* and *Nicoteana*, mean nothing fundamental either for evolution or taxonomy. Such claims of causing "evolution" or "speeding up" of the evolutionary process are not to be considered seriously, since the taxonomic system is of such a nature that no such simple and artificial influence is adequate to explain even the smallest steps of the process that brought it into existence. People who make such claims of causing or speeding up the evolutionary process simply show their complete innocence of the taxonomic system and the movements which are known to have been in operation during paleontological times. Such specious claims are of no value to the taxonomist because if even a chromosome can be injured or modified so as to destroy some of its important structures in which certain potentialities exist, such a fact will have no bearing on the serious study of ascertaining relationships of higher and lower order or of discovering the progressive evolutionary movements which have ploughed their way through the geologic eons.

SERUM REACTIONS.

One of the most remarkable discoveries in the realm of taxonomy in recent years is the fact that plant relationships can be correctly determined by means of serum precipitates. For this great development we are largely indebted to Mez of Koenigsberg. It is well known that in some plants the ordinary morphology is so obscured through reduction or specialization processes that a proper placement in the taxonomic system becomes very doubtful. In such cases, serum reaction determinations become exceedingly valuable and in fact indispensable. The serum method can also be used to check up on the phyletic system that has been developed through a study of the morphology, physiology and chemistry of plants in the classical way. The work accomplished so far confirms in a decided manner the phylogenetic relationships as worked out by Bessey, the writer, and others working purely with the morphological, physiological, and paleontological indications. Of course, the serum reactions probably have their obscurities as well as the morphological systems and are not to be taken as final arbiters in taxonomy. The practical taxonomy will always be built on a morphological foundation, since this is the easiest method of approach and is the only one that is commonly convenient to use.

STUDY OF THE FOOD OF THE BLUNT-NOSED MINNOW, PIMEPHALES NOTATUS.

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INTRODUCTION.

Study of the food of minnows is now recognized as very important by ichthyologists. The public knows the importance of minnows as suitable, natural food for game fishes and other larger food fishes, but still fails to appreciate often the basic need of adequate food for the minnows.

Food of minnows has been studied by a number of investigators, practically beginning in this country with the widespread fish work of Forbes about 1880, as recorded in many papers. An example of recent work on food of several minnow species is that of Breder and Crawford, (1922). Many minnow species have been examined in general surveys, but few in large series of specimens. Studies referring to Pimephales notatus will be cited below.

Most of the specimens used in this study were seined in the Portage Lakes, near Akron, Ohio, a chain of lakes very popular for fishing and resort purposes, and rather typical of the few lakes of such sort in Ohio. (Osburn 1921).

General interest in the fish conditions of these lakes warrants investigation of their minnow food. Mr. E. L. Wickliff, of the Ohio Division of Fish and Game, suggested to the writer study of such species as would be abundant and good food for the game fishes, and likewise which would more likely be to a considerable extent vegetarian, so that they would be in little competition with the young game fishes. Such minnow species might then be suitable for propagation in fish hatcheries and fish ponds. Pimephales notatus (Rafinesque), the blunt-nosed minnow, was for practical reasons selected as best for this initial detailed study of food.

The writer wishes to express his indebtedness to Mr. E. L. Wickliff for suggestions, for some southern Ohio specimens, and for the collecting equipment furnished by the Ohio Division

of Fish and Game, and also his indebtedness to a number of interested students, who at various times in the summer of 1926 helped in the collections, namely Messrs. A. Dobkin, L. Sheinin, H. Cassidy, C. Krill, and also Mr. R. Rice, who helped in 1927.

DISTRIBUTION AND FREQUENCY OF THE SPECIES.

Pimephales notatus, recorded as the most abundant minnow in Ohio, (Osburn 1921), was the most abundant species of Cyprinidæ in every one of the Portage Lakes seined during the period of the collections, indeed nearly five times as common on an average as the next most abundant species, Opsopoeodus emiliæ, which was followed closely by Abramis.

This is somewhat contrary to its distribution in Illinois, where statistical data (Forbes and Richardson, 1908, p. 99) showed it scarce in lakes and far commoner in creeks and small rivers, and in fact less fequent in lakes than 16 other minnow species.

The species lives chiefly over mud bottom, less frequently over sand bottom but also on stony shoals, where they breed, according to Reighard (1925, p. 226), who studied this species in a typical lake. The collections upon which this work is based certainly showed it to be an ideal small lake species.

PREVIOUS STUDY OF PIMEPHALES FOOD.

Forbes, (1878, p. 79) found three specimens "full of dirt with fragments of endogenous vegetation, confervoid algæ, and many diatoms."

Forbes, (1883, p. 73) found nine specimens from various parts of Illinois in which: "Mud made about eighty percent of the contents of the alimentary canal, the remainder consisting of unrecognizable vegetable debris, with a few filaments of algæ. Undeterminable insects occurred in one, and a single specimen of Cypris in another."

Hankinson, (1908, p. 204) says: "The food of this species varies very much, but consists chiefly of small organisms taken from the bottom, from water plants, and from the water. Individuals were frequently seen feeding on the eggs of the black bass, Johnny darter, miller's thumb and sunfish of three species." He noted that some of their own fry were eaten, and that in the spring "midges in various stages of development

formed the chief food." He also found some algæ and Ento-
mostraca and in one case a beetle.

Forbes and Richardson, (1908, p. 120) state: "It is one of
the mud-eating group, the alimentary canal being commonly
packed from end to end with mud containing filamentous algæ
and miscellaneous vegetable debris." Occasionally they found
insect fragments and Entomostraca.

Reighard, (1915, p. 226) says: "the muddy bottom of
protected bays affords it food, for it is a 'mud-eater.'" He
also (p. 242) found a variable diet, indicating similarity to that
given by Hankinson.

Pearse (1918, p. 271) in a study of this and many other
species in Wisconsin Lakes, in commenting upon 60 specimens
for which he studied the food in detail, said: "The blunt-nosed
minnow eats a good deal of silt, bottom debris, and plants,
though entomostracans and insects constitute more than half
its food. Certain individuals had taken foods as follows:
Chironomous lobiferus pupæ, 100; Bosmina longirostris cornuta,
100; oligochaetes, 98; filamentous algæ, 90; silt and debris,
100. These figures show that the minnow is a versatile feeder.
The food in the stomach has always been chewed into fine
pieces."

Pearse, (1921, p. 46) found in five specimens from Lake
Pepin, rather equal quantities of midge larvæ, midge pupæ,
Daphnia, fine debris, and unknown materials.

Thus considerable examination of food has been made in
this common species. But a new survey here of over 300
specimens should give a better view of the variability of its
diet, and give data from Ohio waters from which no such
examination has been made before.

METHODS.

Food was examined in all cases from formaldehyde preserved
specimens which had been collected near shore with a 15 foot,
eighth inch mesh seine. The method of food study was the
customary one, described by Forbes (1878), Pearse (1915, 18,
20), and used by others, as by the writer on Campostoma
(Kraatz 1923). This is the method of estimation of volume
of each class or type of food, expressed in percentage of the
whole food contents of each fish. No quantitative work was
done. This qualitative method gives by mere inspection and

judgment, obviously only approximations of correct percentages. But with care and use of many specimens the approximations become as reasonably accurate as can be expected, and it is the only simple, feasible method available. The worst difficulties are in cases where masses of commingled inorganic and finely divided organic debris must be differentiated for estimates, and where percentages are judged on some large mass, say of a larva of some thickness, over against numerous tiny diatoms or algæ scattered over a wide area. Food items occurring in large quantities were expressed commonly in multiples of tens or fives. But relatively rare items were often apparently correctly expressed as one per cent or two per cent. It must be understood that the numerous fractional percentages, expressed to one decimal point, occurring in the tables, were secured only after averaging groups of individual specimens.

Altogether 315 specimens of the species were carefully examined. In each the entire alimentary canal in the abdominal cavity was taken, measured, cut into pieces and the entire contents squeezed out upon a large glass plate. The mass was evenly spread over the plate in a film of water, and examined with binocular first under X 29, and then X 46, which was adequate to show up most foods and estimate the contents in general, and then examined under low power of compound microscope, usually no more than X 75, which was required to recognize the groups of smaller organisms such as diatoms, and other unicellulars. Although some greater magnifications were used for some minute organisms, it was not necessary for the work presented in this paper.

EXPLANATION OF TABLES.

The detailed findings of food items of all 315 individuals of the species are not given in tables in this paper; they would fill at least 15 pages of tables. In grouping specimens, and averaging foods of a common kind together for all fishes of a group, it was so arranged that in each group (or each entry in the table) there would be fishes from only one lake and one collection, and also of only a small range of lengths. Much space is saved, though countless, detailed diet differences are partly obscured.

In one table (No. 4) a few individuals are selected showing particularly contrasting individual diets.

In reading food percentage figures, there may come inevitably the impression of relative quantities of foods. Naturally this is incorrect. To assist in a corrected idea there should be noted in this connection the figures expressing to what degree the intestine was filled. In all individual specimen data, the writer has intestine length as well as "degree filled" to correlate with length of fish. "Degree filled" is an estimation; if "1" is used, it means the intestine was packed from end to end; if "$\frac{1}{2}$," that it was about $\frac{1}{2}$ full, no matter how distributed. In grouping the fishes the fractions can tell no more than, when for instance the figures $\frac{1}{4}$—$\frac{3}{4}$ occur for 10 fishes, that some of the ten had as little as $\frac{1}{4}$ and other as much as $\frac{3}{4}$ of the intestine filled.

ABBREVIATIONS USED IN THE TABLES.

New (New Reservoir); Nesm. (Nesmith Lake); Long (Long Lake); West (West Reservoir); East (East Reservoir); Turk. (Turkeyfoot Lake); Rex (Rex Lake); S. O. (Southern Ohio, from the Ohio River drainage, but with exact localities for specimens examined unknown. This group was sent to the writer by Mr. Wickliff). In one place in Table 2, an entry of two lines is recorded as "East S." This stands for East Reservoir, Sandy Beach. The latter, a sandy bathing beach, was just one particular collecting place very readily worked, among others on the lake. But it happened that specimens were kept separated from those of other localities on the lake, and incidentally showed some interesting differences in detail of food from most of the fish from other collections.

TABLE I.

Alimentary Canal Contents of *Pimephales notatus*.

Category																
Date of Collection	"	"	"	7-29-26	"	7-6-26	7-2-27	"	"	7-29-26	"	"	7-15-26	"	6-29-26	6-24-26
Locality Collected	"	"	"	Long	"	Nesm.	"	"	"	"	"	"	"	"	.	New
Fish Length, mm.	61-64	50-56	44-49	36-43	51-60	41-47	35-46	60-63	50-54	28-35	50-55	42-49	21-29	50-58	37-49	40-55
Number of Specimens	3	10	10	7	3	2	3	5	5	10	6	4	10	7	2	7
Degree Filled	1/3-1/3	1/10-1/2	1/5-3/4	1/10-1/6	1/2-1/3	1/5-1/4	1/3	0-9/10	1/5-9/10	1/4-2/3	1/3-1	2/3-3/4	1/10-1/2	1/3-3/4	1/2-3/4	1/2-3/4
Inorganic	15.0	13.7	13	8.9	23.3	12.5	1.3	7.5	17.0	15.3	17.0	17.5	5.3	23.7	15.0	11.0
Unrecognizable Organic Debris	20.0	13.3	14.5	14.4	25.3	15.0	10.0	8.7	25.0	22.0	9.0	12.5	6.3	18.0	15.0	6.7
Coccogoneales	5.7	2.4	.8	.3			.7	.1		.4	2.0	.5	.5	2.3	2.5	2.3
Hormogoneales	1.3	.9	.6		1.0			.5	.2	.6	.8					8.0
Diatoms	7.0	3.7	.6	.1	3.7	.5	3.3	4.0	13.8	4.8	10.2	13.5	5.0	5.7	2.5	.7
Protococcales			.3		.3		.1		12.3	18.0	6.3	14.5	21.2	3.5	4.1	1.7
Desmids		.2						.3	2.2	1.4	.8	2.5	.1	.4		
Filamentous Green Algae	3.3	2.0	1.3	2.0			.7	1.7	.4	2.0	1.3	13.3	1.8	6.7	1.0	9.3
Higher Plant Remains	24.3	16.7	5.3	4.3	1.0				4.0		1.7	1.2		.7		2.5
Protozoa								.3	.4	.4			1.0	.3	.3	
Rotifers								.3								
Setae, Annelida	.2	.5	.1			.5								1.4	.3	
Statoblasts, Bryozoa	.5								2.5					.1		
Copepoda	1.0	.2	10.0				1.6	8.7	5.0		.5			7.0	.4	
Cladocera	13.4	9.0	6.0	2.1	41.7		65.0	32.5	12.0	10.0	.5	17.2	1.5	13.3	6.6	38.9
Ostracoda	3.3	9.0	27.5	50.7	1.7		5.0	22.5	5.0	17.5		15.0		4.3	.1	1.4
Amphipoda		5.0														
Water Mites																
Eggs (unknown)	1.0								1.0		.6					
Caddis Larvae and Cases																
Midge Larvae	12.5	3.0	2.9				11.7		1.0		6.2		8.3	16.3	50.5	11.4
Insect Remains	6.7	8.0	25.5	5.7					4.0					19.8	40.0	5.7
Unrecognizable Animal Remains	1.0	.5	.7			1.5			1.0		1.7			.7		

TABLE II.

Alimentary Canal Contents of *Pinephales notatus*.

Date of Collection	8-5-27	"	"	"	7-31-26	"	7-17-26	"	"	7-17-26	7-3-26	6-26-26	"	"	8-5-26	7-20-26
Locality Collected	East	"	"	East	"	East S.	"	"	"	East	"	East	"	"	"	West
Fish Length, mm.	24-36	60-69	50-58	40-48	25-36	61-71	48-58	62-63	50-58	44-49	42-54	49-66	58-61	50-56	33-48	24-29
Number of Specimens	10	4	6	8	12	10	10	3	12	5	6	5	4	10	6	10
Degree Filled	1/5-1/2	1/5-3/4	1/3-1/2	1/2-3/4	1/2-2/3	1/2-4/5	1/3-4/5	3/4-10	1/2-4/5	1/2-9/10	1/2-3/4	1/2-2/3	2/3-4/5	1/3-3/4	1/4-3/4	1/2-3/4
Inorganic	1.1	18.9	16.7	20.3	16.3	15.8	13.8	16.0	14.3	15.0	20.8	17.0	15.0	19.6	15.8	12.5
Unrecognizable Organic Debris	15.2	20.5	20.8	14.4	17.5	4.0	4.7	4.3	6.5	7.0	14.2	11.6	19.5	23.6	16.5	11.5
Coccogoneales	3.3	2.0	1.2	7.3	4.4	2.2	1.8	6.3	10.5	6.2	6.1	.4	1.5	8.3	9.2	16.6
Hormogoneales	.3	3.3	2.5	2.1	13.1	4.0		12.7	10.5	23.4	7.3	.4	.5	2.2	1.7	1.2
Diatoms	2.5	5.8	3.3	2.3	4.3	4.3	6.5	25.0	34.2	21.0	23.8	15.0	2.2	6.8	7.6	4.9
Protococcales	.1		.2		.1	1.1	.3	1.3	2.5	.4	1.5	.2		.5	.3	5.0
Desmids		.5	.8		1.3	.5	.4	1.3	5.5	2.0	.3		1.8	2.0	2.3	1.3
Filamentous Green Algae	.3		.2	1.8	4.3	2.9	2.5	9.0	8.0	2.0	3.1	.8	3.8	6.0	3.8	4.7
Higher Plant Remains	.9	7.0	10.7	6.2	9.3				2.7	.4	1.2	1.6	2.0	3.8	2.5	.3
Protozoa								.7				.3		.1	.2	.3
Rotifers		.5								.2	.4			.1		1.0
Setae, Annelida	.7						.3						1.0	1.0		4.3
Statoblasts, Bryozoa							.3				.5					
Copepoda		1.0		3.8		.3	.3			.3	.4	2.6	1.2	.5	5.0	1.0
Cladocera	13.5	31.5	5.0	3.5	17.1	53.0	65.5		5.0	4.7	8.8	17.5		3.2	4.0	7.6
Ostracoda	9.5	1.3	23.3	40.6	15.8	1.2				.8	10.0		.4	30.0	17.4	27.0
Amphipoda													4.0			
Water Mites						.7										
Eggs (unknown)						.3					.2		1.0		.8	.3
Caddis Larvae and Cases							16.6									
Midge Larvae	11.0	6.2	.8		.7						.4		12.4	13.7	2.0	.8
Insect Remains	8.5	17.5	6.7		.8					8.	2.0		28.0	3.3	1.0	1.7
Unrecognizable Animal Remains	1.6	1.2	1.3		.4	1.3	.5				.4		3.0		.5	.5

TABLE III.

Alimentary Canal Contents of *Pimephales notatus*.

Date of Collection	?	"	"	"	"	7-24-26	"	8-7-26	"	7-24-26	"	"	"	"	7-10-26
Locality Collected	?	"	"	S. O.	"	Rex	"	"	"	"	"	"	"	"	Turk.
Fish Length, mm.	60-71	50-59	40-48	30-39	21-27	44-49	30-35	47-57	34-38	60-65	50-57	40-49	61,62	50-58	42-49
Number of Specimens	6	9	8	10	7	5	5	5	5	6	0	2		10	8
Degree Filled	1/3-1	1/3-1	2/3-1	3/4-1	1/2-4/5	1/4-9/10	1/4-9/5	1/4-1/2	1/2-2/3	1/2-5/6	1/5-2/3	0-1/4		1/2-2/3	0-3/4
Inorganic	55.5	59.7	57.5	66.4	46.4	15.0	11.0	26.0	11.0	19.0	24.2	15.6	15.0	15.3	12.1
Unrecognizable Organic Debris	16.7	10.6	11.4	25.0	25.7	23.0	18.0	41.0	18.0	17.0	21.7	22.2	10.0	13.8	17.1
Coccogoneales	.5	1.4	1.5		1.1	8.0	6.2	8.0	23.6	6.6	7.8	15.8	0	4.3	6.9
Hormogoneales	4.2	14.8	16.1	1.4	.9	.4		.6		.6	2.0		5.0	2.2	6.6
Diatoms	3.7	4.0	8.6	3.6	6.0	15.0	8.4	10.0	1.2	4.8	3.0	3.1		.8	5.6
Protococcales	.2					2.6	5.2	.6		1.2	.8	1.1		.6	1.7
Desmids	.3	.7	.5	1.6	5.7	5.0	6.4	.4		3.4	.3	.6		.1	.4
Filamentous Green Algae	8.2	5.0	3.6	1.3	1.2	6.0	15.0	2.0	2.6	30.0	10.0	10.0		3.5	6.6
Higher Plant Remains	1.2	2.1	.5	.3	.7	3.0	1.6	2.4		2.6	8.3	5.5		13.5	.7
Protozoa		.3	.2	.2	.2									.2	
Rotifers	.2		.1				2.0			.2	.2				.2
Setae, Annelida	.2					.2	.2								.4
Statoblasts, Bryozoa															
Copepoda		.1			.7	1.0	3.0		1.0	1.0	.8			9.0	1.6
Cladocera	3.3	.1		11.4	15.6	0	3.0	17.0		4.6	5.8	19.3		16.9	24.0
Ostracoda					2.0		2.0	9.0		5.0			20.0	5.5	10.4
Amphipoda															.5
Water Mites															.2
Eggs (unknown)															.6
Caddis Larvae and Cases															
Midge Larvae	1.6					3.0	15.0	3.0		9.0	3.4	3.9		3.5	
Insect Remains	.6	.5				2.0	1.0	3.0		6.7	2.8		40.0	9.0	4.3
Unrecognizable Animal Remains	3.3								4.6					.5	1.4

TABLE IV.

Alimentary Canal Contents of *Pimephales notatus*. Specimens Selected to Show Contrasting Diets.

													‖		
Date of Collection	?	?	"	7-20-26	"	"	"	7-17-26	7-3-26	6-26-26	7-20-26	8-5-26	7-20-26	7-15-26	"	6-24-26
Locality Collected	"	S.O.	"	Long	"	"	"	"	"	East	"	West	"	"	"	New
Fish Length, mm.	53	37	50	36	53	51	56	54	52	66	27	55	30	50	21	46
Intestine Length mm.	92	76	67	45	70	71	70	85	62	105	26	68		79	20	64
Degree Filled	1	⅞	1⅓	⅕	½	¾	⅔	⅘	¾	1½	½	⅔	⅓	¾	⅓	⅔
Inorganic	90	70		10	10	2	6	10	15	15	25	8	5	15	3	2
Unrecognizable Organic Debris	2	20		9	3		5	5	10	5	20	5	5	15		12
Coccogoneales	1			1	1	1	5	10	3		30	1				
Hormogoneales	2	7			4	1	65	1	30		1	1				
Diatoms	5	3			2	1	15	60	30		5	1		2	5	5
Protococcales							2	2	1		1		2	5	2	1
Desmids							1	8			1					
Filamentous Green Algae							1	1	10		2					
Higher Plant Remains		90									3		10			
Protozoa																
Rotifers																
Setae, Annelida																
Statoblasts, Bryozoa									1							
Copepoda		5	70					1						5		
Cladocera		5		80	95			1		5	7				20	85
Ostracoda		5	5					1		10		85	80	5		
Amphipoda																
Water Mites																
Eggs (unknown)										5			6			
Caddis Larvae and Cases																
Midge Larvae										15				50	60	
Insect Remains										50						
Unrecognizable Animal Remains																

DISCUSSION OF THE FOOD.

As seen in the tables, inorganic material was found in large amounts in canal contents. Rarely was there a fish without at least a small percentage. On the other hand it was not exceptionally high, averaging from 10 to 30 percent in Portage Lakes fishes. That much might be expected of any fish feeding in shallow water, over muddy bottom, and inclined to a somewhat bottom feeding habit, without its being properly characterized a "mud-eater." In the series of specimens sent by Mr. Wickliff from southern Ohio, (from some parts of the Ohio River drainage) there was a considerable contrast, for inorganic matter was present to a greater amount than 50% on an average. The smallest percentage, 15% to 20% was found in only a few of forty fishes, and several had as much as 90% inorganic matter.

Unfortunately the "unrecognizable organic debris," was often of large percentage. None of this so listed could be distinguished with any certainty whatever. Sometimes it was even hard to separate from inorganic matter, but on close examination showed clear differences from mud particles or crystals, appearing usually as flocculent, irregular bits, finely broken down material, sometimes of greenish color, suggesting that it was often of plant origin. Animal material would most likely be more quickly and fully digested if once sufficiently mechanically broken down, and thus escape discovery.

There were many different plant types. "Higher plants" means that in various specimens pieces of leaf, etc., of seed plants presumably, were found. They may have been small pieces when ingested. In several series of specimens, where there is a rather large percentage, as from East Reservoir, July 31, 1926, and Long Lake, July 29, 1926, it was almost entirely due to the presence of Wolffia in large numbers.

Coccogoneales (unicellular blue-green algæ) and Hormogoneales, (filamentous blue-green algæ), as well as diatoms and Protococcales, (unicellular green algæ and some colonies) were usually easily recognizable by group, and not much digested, that is when recognizable at all. Filamentous green algæ usually occurred in fragments.

In many specimens the total plant food percentage was large, but in almost as many other specimens, the animal food was in excess. In the literature there has been somewhat more reference to its preference for plant food, possibly giving rise

to the idea (together with its possession of a rather long intestine), that it must be vegetarian. Some writers however show its very general diet. The present study does not allow its classification as vegetarian, for the following reasons: the large percentage of animal food frequent, and the unusual prevalence of algæ which it had to draw upon for food.

In explanation of the latter point, it should be noted that during the time of the collections, particularly in the latter half of the summer, of both years, there were found present, particularly in East, West, and New Reservoirs, and also Turkeyfoot lake, tremendous quantities of minute algæ in the plankton, giving to the water a prominent greenish color. This was found to be due to blue-green algæ, of both filamentous types, and tiny floating colonies of cells, like Coelosphaerium and Microcystis. Much collecting was done with tow net, and in the time of greenish water, every drop contained many of these blue-green algæ. All other types, both plant and animal, were relatively rare in this plankton. A real vegetarian fish like the gizzard shad, (Tiffany 1920, 21), would have found this a bounteous feast, and would have been filled with these algæ. It should be noted that in shallow water these algæ were equally prevalent throughout, surface to bottom, where a foot or up to three feet deep, in the very water where the blunt-nosed minnows were collected, which, (except in few individual cases) had eaten relatively much less of the algæ then were present in the water. Pimephales seems to be partly a bottom feeder, though not so much as is Campostoma, (Kraatz 1923).

Animal food was found to be of many types. Unrecognizable animal remains were noted in only a few specimens. But certain kinds of much broken down animal remains may be so readily digested so as to escape listing.

The vast majority of animal organisms were very small. The record for Protozoa and rotifers is probably incomplete.

Entomostraca formed the outstanding animal type of food. Cladocera were most abundant in the largest number of specimens, and seemed to be eaten in large numbers whenever common. In possibly half of the cases they were quite intact, but the rest could be recognized only from antennæ, pieces of shell, or the ephippium. A number of specimens had 80% and more, and one 95% Cladocera. Ostracoda were nearly as common, though in somewhat fewer fish. In some they formed a large percentage, including several with 80% and one nearly

90%. They were usually much broken up. Copepoda occurred in a few fishes, much broken up. In the rare cases where Amphipoda were listed, Hyalella was found broken up considerably.

The largest recognizable animal types were the insects, though Hyalella, mentioned above, was as large as most insects, since on the whole only smaller insects were eaten. In a few cases where adult insects were found they. were much disintegrated. Midge larvæ were far in excess of all other insects. In many instances they were quite intact, and practically in all cases recognizable as midge larvæ. Often the entire chitin covering was found. The larvæ were all very small, and only twice was one over 5 mm. found in the food.

No recognizable fish remains were found. As for eggs eaten, in a number of specimens some eggs were found, all grouped in the tables as "eggs (unknown)." Some of these were insect eggs. One fish only had eaten fish eggs (likewise recorded in same column), forming 5% of its food. Unless there were many fish eggs well digested, Pimephales has a good record on that score, offering a contrast to the findings of Hankinson (1908). On the whole there was less food disintegration than one was led to expect from findings of Pearse (1918).

Conclusions

In view of the striking prevalence of algæ in the waters, with a lesser ingestion of these algæ than a real vegetarian would show, and in view of the large proportion of Entomostraca taken, it seems that Pimephales is as much an animal feeder as plant feeder, if not more so. It is impossible to say that the species has any food preferences, and also impossible to show that the blue-green algæ were for any reason somehow repellent, or that other algæ would be taken in preference to blue-greens, if present.

Pimephales is best regarded as a general feeder, preferring all small food organisms, and as a fish versatile in a high degree, as has been shown more or less also in previous studies, principally by Pearse (1918). It is not characteristically vegeterian, nor carnivorous, nor specifically a plankton feeder, but a general feeder upon all small organisms and debris taken about equally from plankton and from the bottom of its habitats.

Since Pimephales notatus is by far the most abundant minnow, at least in the Portage Lakes, and very generally common in Ohio, it is one of the most outstanding food for the

game fishes of the region. Also, this natural food species, since it thrives so well, will undoubtedly increase somewhat more under general regulation of minnow seining. This increase comes without extra cost. While this minnow is not a vegetarian, as indeed very few species are, it is not much in competition with game fishes for food, except in the very young stages of the game fish life. It certainly is not harmful because not carnivorous on such young. Pimephales should therefore be one of the minnows most favored, and should be found desirable for various fish ponds and lakes.

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A SURVEY OF RATES OF WATER LOSS FROM LEAVES.*

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INTRODUCTION.

This paper is a record of data collected showing water loss from leaves from a number of plants growing in several habitats. As many different species as possible were tested in the time at the writer's disposal. At first a mere list of water loss data was intended, but a number of new phases have arisen during the course of the tests. It is probable that, as the work progresses and more is known about the general field, still others will arise.

Representatives of three of the four great groups of plants have been studied, namely from the Spermatophytes (including both Angiosperms and Gymnosperms), Pteridophytes and Bryophytes. The greatest number is from the Spermatophytes since they make up such a large proportion of our vegetation. The method used in collecting data was not applicable to the Thallophytes and submerged aquatics.

In collecting these data, representatives were selected from several different habitats so that comparisons of their water loss might be made. An attempt has also been made to study the diurnal rates of water loss from a small number of plants.

The water loss from plants has an extremely important bearing on their distribution and their survival. Heretofore, largely because of their economic importance, much more has been done with agricultural plants in this relation than with other types. And too, in nearly all cases potted plants, plants growing in the laboratory, in the greenhouse, or otherwise under abnormal conditions, have been used. This work is an attempt to measure the loss of moisture under as nearly normal conditions as is possible with present day methods. The loss has not been considered as a "power of the leaf", but rather as a phenomenon over which it has no control. Water loss is due to external and internal environmental factors rather than a specific "ability" of the leaf "to give off water."

As far as the writer has been able to discover, very little work has been done in the way of a general survey of water

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loss from leaves.* This is likely due to a lack of a practical quantitative method of determination, which can be carried into the field and used readily under natural conditions of the many different habitats.

METHOD USED.

The cobalt chloride paper test was used, as devised by Stahl (19), improved by Livingston (9), Livingston and Shreve (10), and more recently by Sayre (12). Livingston's and Shreve's method was quite an improvement over that of Stahl, and has been used successfully by a number of workers. However, it should be noted, that the results obtained by this method are entirely qualitative and relative.

To secure quantitative results Sayre (12) standardized cobalt chloride paper by the following method. Filter paper (Whatman No. 1) was saturated in a 3% solution of cobalt chloride, dried in an oven until the blue color appeared, and then continued in a desiccator containing anhydrous calcium chloride. Dry weight was then obtained, after which they were placed in a moist chamber and left until they attained a full pink color, and reweighed. The difference in weight represented the amount of water vapor necessary to change the blue paper to a full pink color.

From these data it is seen that if the cobalt paper is properly applied to a leaf surface the actual water loss can be obtained. A number of investigators have used small glass plates to cover the cobalt papers in protecting from atmospheric moisture, and to hold the papers in place on the leaf to be tested. Sayre (12) used celluloid instead of glass. The cobalt paper was cut in circular areas with a punch $\frac{15}{32}''$ in diameter. The celluloid was cut in strips $\frac{3}{8}'' \times 1\frac{1}{2}''$. The cobalt paper was then fastened at each end and on the same surface of the strips by means of gummed reënforcements for notebook paper. These were of greater diameter than the width of the strips, so extended over the sides and end. A reënforcement was moistened and applied near one end of the strip, the perforation being covered by the celluloid. While still moist the strip

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*The following workers have contributed to our knowledge of water loss from various species: Livingston (9), Shreve (17), Trelease (20), Meyer (12 and 13), Shive and Martin (16), Cribbs (4 and 5), McGinnis and McDougall (11), Bakke (1 and 3), Delf (6), Kiesselbach (8), Rosenberg (15), and others. With the exception of Kiesselbach, these workers used Stahl's (19) Cobalt Chloride Method, the same as improved by Livingston (9), Livingston and.Shreve (10) and by Sayre (12).

was inverted, cobalt paper placed opposite the perforation in reenforcement and a dry reenforcement placed over the paper so that the dry gummed surface was in contact with the moist gummed surface projecting over the edges. The gummed surfaces were pressed tightly together. These held the cobalt paper in position with only the one surface exposed, which was to be placed next to the leaf, and the other surface could be seen through the celluloid. After cobalt paper was attached to both ends of strip in the above manner, the strip was folded along the short axis through the center. This then made a clip which could be readily clamped on a leaf with a hygrometric paper exposed to each surface. In this work the clips were attached to a leaf surface by means of small clamps (Denison Card Holder, No. 42). The hook at the end was convenient for attaching a slip of paper with number of the leaf and time at which the clip was applied. Fifty or sixty clips were made so that time would not be lost in waiting for them to dry in a desiccator. The clips were kept in desiccators made of wide-mouthed bottles, of convenient size for carrying, with anhydrous calcium chloride. These clips were used until they became soiled or wet. The desiccating process can be greatly speeded up by placing the bottles in bright sunlight or near a fire. As color standards, a paper may be kept in a small desiccator for the blue color. For the pink standard a clip which has been in contact with a leaf surface until a full pink color has appeared, may be carried about on a leaf, or in a bottle.

The paper used in collecting the data given below was standardized to .05981 gram of water per 100 square centimeters. That is, it took .05981 gram of water to change the blue (dry) cobalt chloride paper to a full pink color. So, if it takes 1 minute to change the blue to pink, the grams of water vapor absorbed per 100 square centimeters in one hour would be 60 times .05981 gram. Meyer's (12) formula was used in making the calculations. It is as follows:

$$\frac{.05981 \times 3600 \text{ (Sec. in one hour)}}{T \text{ (Time of color change)}} = G \text{ (Grams of water vapor)}.$$

In each case the wet and dry bulb temperatures were taken in order that the relative humidity might be determined. The thermometers were kept in a shaded place as near the leaves being tested as was possible. Shreve (17) showed that temperature of the air immediately surrounding the leaf may

be safely used instead of the temperature of the clip itself. Leaves in good condition as far as could be determined were selected in every case except where indicated. In practically all cases five readings were taken at a single time, each on different leaves, and the time of color change averaged for each surface. So that in the following lists and graphs the time of color change indicated is an average for a given surface, and not for a single leaf or a single reading. The time of change has also been standardized for a temperature of 20 degrees C. In doing this Livingston's and Shreve's (10) table was used.

Bakke (1) pointed out the fact that the only external environmental factor directly affecting water loss from a leaf surface by cobalt chloride paper is temperature. This can be standardized to a given degree by Livingston's and Shreve's (10) table.

The relative humidity may have an effect through the layer of air imprisoned between the leaf surface and the cobalt paper. This effect must be very small since the moisture in this layer is absorbed almost instantly and the relative humidity is 0 in a very short time after the clip is applied.

The direct effect of light is small since but little light can pass through the cobalt paper. The relative humidity and light intensity may have a far reaching indirect effect. The direct effect of air currents is also removed. Some of the other factors which may have effect upon water loss have been pointed out by Kiesselbach (8) and Cribbs (4 and 5).

The cobalt chloride method of measuring water loss measures the water vapor given off at a particular instant, and is not measuring accumulative quantities, as does the potometer method. For this reason it is not safe to compare the two means of determination. In the potometer method light, relative humidity and wind have a direct effect on the amount of water lost. Because of these differences Dr. E. N. Transeau suggested to the writer the term "Standard Water Loss" from the leaf surface, as being the water loss measured by the cobalt chloride method.

The chief sources of error in the cobalt chloride method are:

1. The hygrometric paper absorbs some moisture from the atmosphere during transfer from the desiccator to the leaf. In every case this transfer was accomplished as quickly as possible, and took but a few seconds.

2. There may be a source of error in determining when to take the reading. This difficulty may be, at least partly, removed by having color standards as suggested.

3. Lateral leakage from surrounding air may also be a source of error. This error seems to be quite small, for in a number of instances, usually on upper surfaces, the test papers remained unchanged for two hours.

4. Pressure of the clip on the leaf surfaces may cause some change in size of the opening of the stomata.

5. Average leaves may not be selected for the tests. However, as tests were made on five leaves each time and an average taken for the standard water loss, it is believed that most of this source of error is removed.

MEASUREMENTS OF WATER LOSS.

Standard water loss data was collected on the following 123 species during the fall of 1925, spring, summer and fall of 1926. Excepting tests for diurnal rates, all readings were taken between the hours of 10:00 A. M. and 1:30 P. M. during which time the stomata were expected to be open and the maximum rate of standard loss taking place. As some of the series of readings later showed, this is not always the case. The maximum rate sometimes occurred early in the day, as shown by the diurnal study. Shreve (18) found this to occur among some desert species. Although the readings do not necessarily represent the maximum rate of standard water loss, they still retain a certain value as a survey.

This list contains plants from a wide range of environmental conditions. Some examples are as follows:

Sphagnum Bog—*Vaccinium, Menyanthes, Sarracenia, Decadon, Alnus, Hibiscus,* and *Rhus Vernix;* Swamp—*Cephalanthus, Sium, Quercus palustris, Rosa carolina, Ilex, Alisma, Iris, Glyceria, Impatiens,* etc.; Aquatic—*Polygonum amphibium, Typha, Sagittaria, Dianthera,* etc.; Flood plain—*Salix, Aesculus, Allium, Angelica, Arctium, Asimina, Celtis, Prunus* and *Urtica;* River Bank—*Ambrosia, Elymus, Platanus,* etc.; Talus slope— *Sambucus racemosa, Epigea, Epipactus, Gaulthera, Cypripedium, Rhododendron* and *Betula;* Ledge—*Sullivantia* and *Polypodium;* Plains—*Buchloe;* Prairies—*Silphium laciniatum;* Agricultural plants—*Zea, Solanum tuberosum, Bromus,* and *Phleum;* "Weeds"—*Amaranthus, Xanthium, Chenopodium, Convolvulus,*

Abutilon, Lactuca, Arctium, Setaria, Digitaria, Taraxacum, Polygonum virginianum, Leonurus, Erigeron, Cirsium, and *Ambrosia.*

TABLE I.

MEASUREMENTS OF WATER LOSS.

NAME OF PLANT	Date	Temp. of air in Degrees C.	Av. No. of Secs. for Upper Surface	Av. No. of Secs. for Lower Surface	Corrections made for Temp. (Upper)	Corrections made for Temp. (Lower)	Grs. of Water Lost Per Hour (Upper)	Grs. of Water Lost Per Hour (Lower)	Time of Reading	Relative Humidity
Abies Cilicica Carr...........	4-21'26	17.7	824	1360	716.5	1182 6	.3	.182	12:30	41
Abutilon Theophrasti Medic....	6-25'26	26.9	158	44	239.3	66.6	.89	3.23	11:40	52
Acer platanoides L.............	10-15'25	14.4	1605	247	1132.3	173.9	.18	1.23	12:30	89
Acer rubrum L................	7-16'26	26.6	1780	116	2656.7	173.1	.081	1.243	12:30	56
Acer saccharinum L............	10- 8'25	14.4	1995	150	1404.9	105.6	1.532	2.038	12:25	62
Acer saccharum L.............	5-19'26	18.0	2940	1344	2601.7	1189.3	.082	.181	11:40	82
Aesculus glabra Willd.........	5-25'26	18.6	3624	2004	3324.7	1838.5	.0647	.117	12:35	89
Argopyron repens (L.) Beauv..	7-14'26	24.4	76	89	98.7	115.5	2.181	1.864	12:49	43
Alisma Plantago-aquatica L....	6- 1'26	26.6	60	60	65.9	65.9	3.267	3.267	12:55	75
Allium Tricoccum Ait........	4-10'26	13.3	642	383	419.6	250 3	.513	.802	12:11	55
Alnus rugosa (Du Roi) Spreng.	7-15'26	23.8	....	840	....	1063.2	....	.202	11:40	58
Ambrosia trifida L.............	7-14'26	19.4	168	95	161.5	91.3	1.333	2.358	10:45	67
Amaranthus retroflexus L.......	6-26'26	26.1	47	49	68.1	71	3.162	3.032	12:05	57
Angelica atropurpurea L.......	5- 6'26	26.6	589	59	879	88	.244	2.446	1:25	35
Arctium minus Bernh.........	5-31'26	24.7	474	108	632	144	.3406	.149	11:50	83
Asimina triloba Dunal........	8- 6'26	28.6	1440	125	2400	208.3	.0897	1.033	10:20	80
Aspidium cristatum (L.) Sw...	6-19'26	19.44	492	177	473	170.1	.455	1.265	11:45	67
Aspidium marginale (L.) Su...	4-14'26	14.1	2322	1564	1601.3	1078.5	.134	.199	11:05	46.5
Barbarea vulgaris R. Br.......	4-14'26	17.7	149.3	97.5	131.1	85.5	1.642	2.518	12:00	9
Berberis thunbergii D. C.......	7- 3'26	30.0	1428	402	2596.3	730.9	.082	.294	11:52	58.5
Betula lenta L.................	7- 8'26	25.2	520	38.3	712.2	52.4	.302	4.10	12:05	77
Bromus inermis Leyss.........	7- 1'26	31.1	955	3172	1836.3	6100	.117	.035	12:35	39.5
Buchloe dactyloides (Nutt) Engelm....................	7-12'26	26.1	1745	1745	2528.9	2528.9	.085	.085	10:33	54
Cannabis sativa L., (Male)......	8-26'26	25.2	868	88	1189	120.5	.0181	1.786	11:30	75
Cannabis sativa L. (Female)....	8-26'26	25.2	570	91	780.8	124.6	.0275	1.728	11:30	75
*Carica papaya Linn..........	7-20'26	34.4	....	662	....	1539.5	....	.167	10:45	39
Castanea dentata(Marsh)Borkh.	7- 8'26	26.3	520	296.6	764.7	436.4	.281	.493	12:55	71
Catalpa bignonioides Walt......	7-13'26	20.5	2116	311	2181.4	320.6	.0987	.671	11:45	74
Celtis occidentalis L...........	8- 6'26	29.7	1338	132	2389.2	235.7	.09	.913	11:00	81
Cephalanthus occidentalis L.....	6-22'26	23.3	1608	37	1960.9	45.1	.109	4.774	11:15	64
Chenopodium album L.........	6-25'26	28	150	128	241.9	206.4	.89	1.04	12:13	49
Cirsium arvense (L.) Scop......	6-24'26	27.2	518	60	796.9	92.3	.271	2.33	11:30	51
Convolvulus sepium L..........	6-25'26	28.6	130	146	216.6	243.3	.994	.884	1:15	40
Corylus americana Walt........	6-26'26	26.3	1614	59	2375	86.7	.090	2.48	12:15	52
Crataegus sp..................	5-13'26	18.8	2400	104	2242.9	97.1	.095	2.21	12:30	87
Cypripedium hirsutum Mill.....	7- 9'26	26.9	339	71	513.6	107.5	.419	2.002	11:20	85
Decadon verticillatus (L.) Ell...	7-15'26	25.2	2755	77	3773.9	105.4	.057	2.042	12:55	60
Dianthera americana L........	7-14'26	20.83	92	181	96.8	190.5	2.22	1.13	10:23	57.5
Digitaria sanguinalis (L.) Scop.	6-25'26	27.7	924	304	1466.6	482.5	.146	.446	12:30	46.5
Elymus virginicus L...........	7-22'26	37.2	475	....	1283.7	....	.167	....	12:05	43.5
Epigaea repens L..............	7- 9'26	26.6	155	64	231.3	95.5	.930	2.25	11:20	87

*Growing in Greenhouse.

TABLE I—Continued.

Name of Plant	Date	Temp. of air in Degrees C.	Av. No. of Secs. for Upper Surface	Av. No. of Secs. for Lower Surface	Corrections made for Temp. (Upper)	Corrections made for Temp. (Lower)	Grs. of Water Lost Per Hour (Upper)	Grs. of Water Lost Per Hour (Lower)	Time of Reading	Relative Humidity
Epipactis sp.................	7- 9'26	27.7	500.6	66	794.6	104.7	.270	2.05	12:50	70
Equisetum arvense L..........	7- 1'26	30.2	98	250	181.4	462.9	1.175	.465	12:15	34
Erigeron annuus (L.) Pers.....	6-23'26	27.5	3372	2844	5268.7	4443.7	.040	.048	12:15	57.5
Eupatorium perfoliatum L.....	6-23'26	25	1884	47	2595.9	63.5	.084	3.39	1:10	56
Fraxinus americana L..........	10-14'25	13.3	2435	170	1591.5	111.1	.135	1.938	11:37	94
Gaulthera procumbens L........	7- 9'26	26.6	943.3	71.6	1407.9	106.8	.152	2.016	10:13	87
Gleditsia triacanthos L..........	10-13'25	15.56	230	133	172.9	100	.1245	2.153	12:30	68
Glyceria nervata Trin.........	7- 2'26	30.28	50	672	92.4	1244.4	2.33	.173	12:55	48
Glyceria septentrionalis Hitche.	7- 2'26	30.00	54	90	98.1	163.6	2.194	1.316	12:20	57
Hepatica acutiloba D. C.... ...	4-12'26	6.9	3121	947	1333.7	404.7	.161	.532	1:38	70
Hibiscus moscheutos L.........	7-15'26	23.89	......	168	....	212.6	....	1.012	11:26	58
Ilex verticillata (L.) Gray......	6-19'26	19.4	2652	128	2550	123	.084	1.75	......	67
Impatiens biflora Walt........	7- 2'26	30.56	54	33	101.8	62.2	2.115	3.46	12:05	60.5
Iris versicolor L...............	6-22'26	23.6	45	56	56.2	70	3.83	3.075	11:30	60.5
Juglans nigra L................	7- 3'25	30.8	2460	1116	4641.5	2105.6	.046	.102	12:25	54
Kalmia latifolia L.............	7- 9'26	26.6	788.3	63.6	1776.5	94.7	.121	2.273	10:00	87
Lactuca scariola integrata Gren. und Godr.............	6-21'26	25.8	1212	165	1731.4	235.7	.124	.913	10:30	64
Leersia oryzoides (L.) Su.......	7-22'26	27.7	607	93	963.4	147.6	.223	1.458	10:15	78
Leonurus cardiaca L...........	6-21'26	26.1	1818	203	2634.7	294.4	.081	.731	10:50	64
Lonicera sp..................	5-14'26	17.2	1644	59	1381.5	49.5	.155	4.349	12:20	72
Lysimachia nummularia L......	4-15'26	4.4	1103	509	396.7	183	.542	1.176	12:10	61
Malva rotundifolia L..........	10- 7'25	23.06	365	123	439.7	148.1	.4896	1.453	1:05	65
Maclura pomifera (Raf.) Schn	8- 6'26	31.6	1572	58	3144	116	.068	1.856	12:31	65
Menyanthes trifoliata L.......	7-16'26	23.33	320	84	390.2	102.4	.551	2.102	10:05	72
Mitchella repens L............	4-13'26	8.8	3492	632	1695.1	306.7	.127	.702	12:40	53
Nepeta cataria L..............	4-14'26	17.7	392	137	340.8	119.1	.631	.180	12:15	9
Nepeta hederacea (L.) Trevisan	4- 7'26	17.5	908	92	776	78.6	.277	2.739	12:25	61
Oenothera biennis L...........	6-21'26	26.9	1020	958	1545.4	1451.5	.139	.148	11:15	61.5
Ophioglossum vulgatum L......	6-30'26	28.3	370	142	606.5	232.1	.355	.927	10:30	66
Osmunda cinnamomea L........	7-16'26	25.8	872	101	1245.7	144.2	.172	.149	12:20	53.5
Pastinaca sativa L.............	10-23'25	15.00	607	102	486.8	74.4	.442	2.89	12:15	39
Phleum pratense L.............	7-14'26	23.89	138	143	174.6	181	1.233	1.189	12:40	48
Picea Abies (L.) Karst........	4-27'26	12.2	1402	1402	854	854	.252	.252	12:45	43
Pinus austriaca Hoss..........	5-19'26	17.78	261	261	226.9	226.9	.948	.948	12:20	79
Pinus contorta Dougl.........	4-23'26	18.8	252	210	233.3	185.1	.9229	1.163	12:30	58
Pinus rigida Mill..............	4-24'26	14.4	255	286	179.5	201.4	1.199	1.069	12:30	72
Pinus strobus L...............	4-23'26	18.8	882	890	816.6	824.1	.2636	.261	11:50	58
Pinus sylvestris L..............	4-20'26	13.3	892	988	583	645.7	.369	.333	12:30	32
Plantago lanceolata L..........	10- 8'26	14.4	66	71	464	50	.464	4.306	12:22	62
Plantago major L.............	10- 8'25	14.4	121.6	60	85.6	42.2	2.503	5.102	12:50	62
Platanus occidentalis L.........	8- 6'26	31.3	1434	64	2811.7	125.4	.076	1.717	11:58	64
Polygonum amphibium L.......	7-15'26	22.7	50	50	58.8	58.8	3.661	3.661	11:15	58
Polygonum virginianum L......	7-12'26	28.8	2675	124	4533.8	210.1	.047	1.024	12:45	70
Polypodium vulgare L.........	4-10'26	13.8	3459	1563	2337.1	1056	.092	.203	12:45	51.5
Polystichum acrostichoides (Michx.)...................	4-12'26	6.9	4615	726	1972.2	310.2	.109	.694	1:32	71
Polytrichum ohioense R. & C...	7- 2'26	30.5	25	25	47.1	47.1	4.571	4.571	12:40	42.5
Populus deltoides Marsh.......	10-15'25	15.0	455	210	332.1	145.9	.648	1.475	12:15	89
Potentilla canadensis L.........	6-23'26	26.1	493	33	714.3	47.5	.301	4.504	12:50	48
Prunus serotina Ehrh.........	5- 7'26	27.7	......	130	....	206	....	1.045	12:10	31

TABLE I—Continued.

Name of Plant	Date	Temp. of air in Degrees C.	Av. No. of Secs. for Upper Surface	Av. No. of Secs. for Lower Surface	Corrections made for Temp. (Upper)	Corrections made for Temp. (Lower)	Grs. of Water Lost Per Hour (Upper)	Grs. of Water Lost Per Hour (Lower)	Time of Reading	Relative Humidity
Quercus bicolor Willd..........	6-18'26	25.2	1812	876	2482.1	1200	.086	.179	11:45	77
Quercus palustris Muench......	6-23'26	26.1	1848	112	2678.2	162.3	.080	1.326	12:00	57
Rhododendron maximum L.....	7- 7'26	22.2	1956	105.6	2248.2	121:3	.095	1.775	10:20	86
Rhus Vernix L................	7-15'26	24.4	3001	282	3897.3	366.2	.055	.587	12:32	48
Rosa carolina L................	6-17'26	29.4	1515	60	2657.8	105.2	.081	.204	1:00	63
Rubus occidentalis L..........	5-20'26	16.9	4020	93	3322.3	77.6	.064	2.774	12:45	62
Rumex altissimus Wood........	7-12'26	28.6	206	133	343.2	221.6	.627	.971	12:30	72
Sagittaria sp..................	6- 1'26	22.2	112	82	128.7	94.2	1.673	2.285	12:40	73
Salix babylonica L............	10-14'25	13.8	1585	171	1070.9	115.5	.201	1.864	12:30	100
Salix discolor Muhl...........	6-18'26	22.5	92.8	53.2	107.9	61.8	1.995	3.484	12:00	63
Salix nigra Marsh.............	7-22'26	29.1	172	60	296.5	103.4	.726	2.082	11:00	70
Sambucus canadensis L........	6-22'26	23.6	3084	44	3855	55	.055	3.914	11:45	58.5
Sambucus racemosa L........	7- 7'26	25.2	2520	2136	3452.1	2926	.0623	.735	12:45	58
Sarracenia purpurea L........	7-16'26	23.3	512	454	624.3	553.6	.344	.388	10:20	66
Setaria italica (L.) Beauv.....	7-14'26	21.9	960	1331	1078.6	1495.5	.199	.143	12:00	54
Silphium laciniatum L........	7-12'26	25.2	113	124	154.7	169.8	1.391	1.268	10:10	54.5
Silphium perfoliatum L........	7- 1'26	29.4	1788	1200	3136.8	2105.2	.008	.102	11:20	41.5
Sium cicutaefolium Schrank....	6-18'26	22.2	312	60	358.6	68.9	.600	3.125	11:05	69
Solanum Dulcamara L........	10-24'25	15.0	......	483	....	352.5	....	.610	12:30	39
Solanum tuberosum L..........	6-26'26	26.6	235	258	350.7	385	.613	.559	10:45	54
Sullivantia Sullivantii (T.& G.) Britton....................	7- 8'26	25.5	615	180	8541	250	.025	.845	11:45	78
Taraxacum officinale Weber....	7- 3'26	31.1	612	92	1176.9	176.9	.182	1.217	1:15	52
Typha angustifolia L..........	7-16'26	25.5	115	216	159.7	300	1.348	.717	11:30	64
Typha latifolia L..............	5-31'26	26.6	64	52	95.5	77.6	2.254	2.774	12:30	83
Ulmus americana L............	10-13'25	13.8	1330	130	904.7	88.4	2.370	2.435	12:12	77
Urtica gracilis Ait.............	5-20'26	16.6	2076	66	1674.1	53.2	.128	4.047	1:15	64
Vaccinium macrocarpon Ait....	7-16'26	26.6	635	108	947.7	161.2	.227	1.335	12:50	54
Verbascum Thapsus L.........	3-25'26	5.5	1237	455	479.4	176.3	.449	1.221	1:15	92
Vinca minor L.................	3-24'26	16.1	4152	203	3243.7	158.5	.066	1.358	12:11	77
Vitis cordifolia Michx..........	5-26'26	20.5	42	384	43.2	395.8	4.984	.544	1:00	55
Xanthium sp..................	7-14'26	25.0	91	63	122.9	85.1	1.751	2.530	1:04	41
Yucca sp.....................	3-29'26	9.7	4130	3702	2128.8	1908.2	.1011	.1128	1:28	58.5
Zea mays L..................	6-25'26	24.1	139	122	178.2	156.4	1.208	1.376	10:30	61

A study was made of the standard loss from evergreen plants. The readings were taken before growth had started in the spring. The leaves were approximately one year old.*

*The averages which follow were obtained first by averaging the standard loss for the upper and lower surfaces of the leaves as given in the above list of plants (i. e. these quantities of water vapor represent the sum of the loss from 50 sq. cm. of upper surface and 50 sq. cm. of the lower surface). Then these averages were averaged for the following groups.

I. Spermatophytes.

  A. Gymnosperms.

    1. *Abies Cilicica*
    2. *Picea abies*
    3. *Pinus austriaca*
    4.   "   *contorta*
    5.   "   *rigida*
    6.   "   *strobus*
    7.   "   *sylvestris*

The average standard loss for this group was .5481 gm. The greatest loss was from *P. rigida*—1.134 gm. The smallest was from *A. Cilicica*—.241 gm.

  B. Angiosperms—(Leaves had passed through the winter. Exact age was not known.)

    1. *Barbarea vulgaris*
    2. *Lysimachia numularia*
    3. *Mitchella repens*
    4. *Nepeta Cataria*
    5. *Nepeta hederacea*
    6. *Verbascum Thapsus*
    7. *Vinca minor*
    8. *Yucca* sp.

The average for the group was .8523 gm. *Barbarea* was highest—2.08 grams, and *Yucca* was lowest—.1065 gm.

II. Pteridophytes.

    1. *Aspidium marginale*
    2. *Polypodium vulgare*
    3. *Polystichum acrostichoides*

The average for the group was .2401 gm. *Polystichum* was highest—.4015 gm. *Polypodium* lowest—.1525 gm.

Some readings were taken on a sugar maple and two pines growing near one another. The readings were taken within one hour and on the same day. The maple leaves were approximately 20 days old and the pine leaves about 1 year old. The results are as follows:

    Acer saccharum............................ .104 gm.
    Pinus sylvestris............................ .110 "
    Pinus austriaca........................... .948 "

In order to get a comparison between the standard loss for corn, the potato and some common "weeds," growing along beside the corn and potato, the following data were collected:

    1. *Abutilon Theophrasti*............... 2.065 grams
    2. *Amaranthus retroflexus*.............. 1.848 "
    3. *Chenopodium album*................ 2.889 "
    4. *Convolvulus sepium*................. 2.132 "
    5. *Digitaria sanguinalis*............... .295 "
    6. *Setaria italica*...................... .171 "
    7. *Xanthium* sp...................... 2.14 "
    8. *Solanum tuberosum*................ 1.361 "
    9. *Zea mays*......................... 1.786 "

McGinnis and McDougal (11) made a number of similar comparisons of several "weeds" with corn, using the cobalt chloride method as developed by Livingston and Shreve (10). Their plants were of necessity grown in the greenhouse and data were obtained during the months of February, March and April. The writer took a series of readings in August on a single *Zea* plant and a similar series simultaneously on an *Amaranthus* plant, growing near the corn. Fig. 1 shows the results graphically.
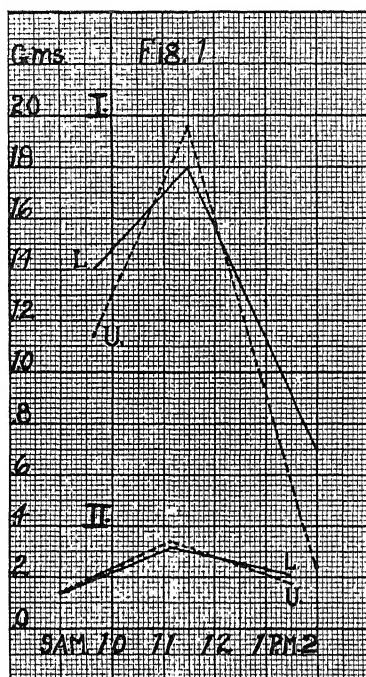
Fig. 1. I. Graph showing the standard water loss for the upper (U) and lower (L) surfaces of *Amaranthus retroflexus* leaves. II. Graph showing the standard water loss for the upper (U) and lower (L) surfaces of *Zea mays* leaves. Readings on both plants were taken simultaneously.

An effort was made to test out the difference in standard loss of rolled and non-rolled leaves of the same species. The two bunches of *Elymus virginicus* selected were growing within a few feet of each other on a river bank. One bunch showed rolled leaves and the other did not. The leaves tested were not on the same plant but on different plants in each cluster. The results are as follows:

　　　　　Rolled leaves were losing................ .167 gram
　　　　　Unrolled leaves were losing.............1.696 grams

Bakke and Livingston (3) pointed out the fact that water loss is different for leaves occupying different positions on the same plant. This has been confirmed in the case of a large specimen of *Ulmus americana*. Readings were taken at an altitude of approximately 40 feet, and others on leaves which could be reached while standing on the ground. The lower readings were started at 11:45 and the upper at 12:00. The leaves were more or less shaded in both positions. The tests were made in August. The tree apparently had an abundant water supply as it was growing on a river bank. No satisfactory color change was obtained in either upper surface. In the upper position only one paper changed color on the lower surface after an exposure of 50 minutes. The other papers were left on for 1 hour and 20 minutes without change. In the lower position, papers on the lower surfaces changed in the average time of 38 minutes 24 seconds. The standard water loss was .0401 gm. per 100 square centimeters in one hour at a temperature of 20 degrees C. Calculations for the upper position were not made because of unsatisfactory color change. The rate for the leaves in the higher position was evidently much lower.

A number of readings were taken simultaneously on young and mature leaves in order to get a comparison. The results were as follows:

		YOUNG	MATURE
1.	*Silphium perfoliatum*	.2085 gm.	.788 gm.
2.	*Corylus americana*	.285 "	1.2865 "
3.	*Arctium minus*	.5235 "	3.5955 "
4.	*Cephalanthus occidentalis*	.193 "	1.239 "
5.	*Chenopodium album*	.9665 "	2.8895 "
6.	*Convolvulus sepium*	.939 "	2.1325 "
7.	*Sarracenia purpurea*	.118 "	.732 "
8.	*Typha latifolia*	4.816 "	2.51 "

It is interesting to note that Typha latifolia is the only species examined in which the young leaves were simultaneously losing more water than the mature leaves. Meyer (13) has been able to express more juice from mature leaves than from young.

A series of readings were made on *Acer saccharum, Rosa carolina* and on *Catalpa bignonioides*, at certain intervals during the summer. The leaves were marked when the first reading was made. The same leaves were tested each time, excepting in the last reading on the *Acer* all the marked leaves had dis-

appeared except two.   Others were selected which were approxi-
mately in the same position.   Also all but one of the tagged
leaves of Rosa had disappeared by the time of the second
reading.

The readings on *Rosa* were made first on May 17, and showed
a standard loss of .933 gm.   One month later, at the same time
of day, readings were again taken.   The loss then was .141 gm.,
showing a decrease of .792 gm. per unit area for the more mature
leaves.
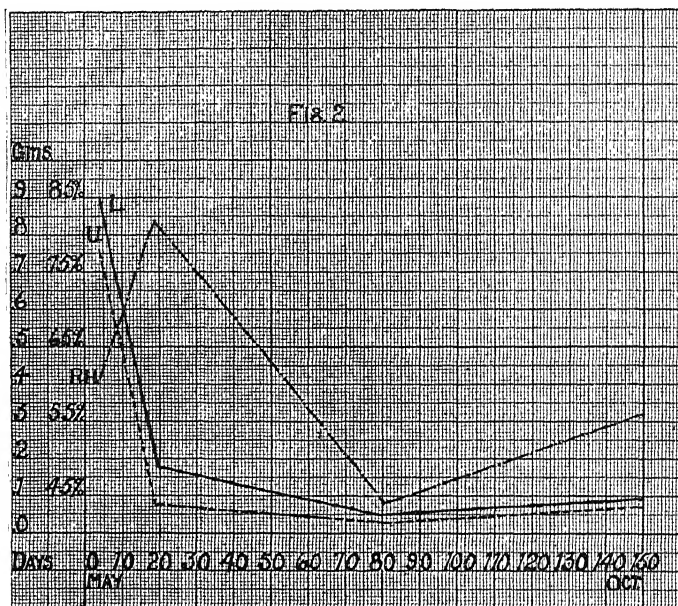
Fig. 2.   Graph showing standard water loss from leaves of *Acer saccharum* from
the time they were unrolling from the buds until they were approximately 150
days old. L, lower surface. U, upper surface. R. H., relative humidity.

On July 13 the first readings were taken on *Catalpa*.   The
loss was found to be .4475 gm.   On August 31 readings were
again taken on the same leaves at the same time of day.   The
result obtained this time was .2559 gm., or .1916 gm. decrease
for the older leaves.

On May 4 readings were started on *Acer saccharum*.   The
leaves were just unrolling at this time.   Three other readings
were taken during the summer and autumn.   The graph,
Fig. 2, shows the results.

While working with very young leaves it was found that
several, notably *Convolvulus, Psedera quinquefolia* (L) Greene

and *Vitis cordifolia* Michx. lost water more rapidly along the midrib than on the remainder of the leaf. This was determined by the fact that a pink streak appeared in the cobalt paper which was directly over the midrib or a large vein. The remainder of the paper continued blue for some time.

Starting at 12:45 P. M., on July 7, a series of tests were made extending through 24 hours on *Sambucus racemosa.* The plant was growing on a talus slope, east exposure, very sandy soil, and protected by a high, cave-like cliff. There was a large spring a few feet away, so it likely had a plentiful
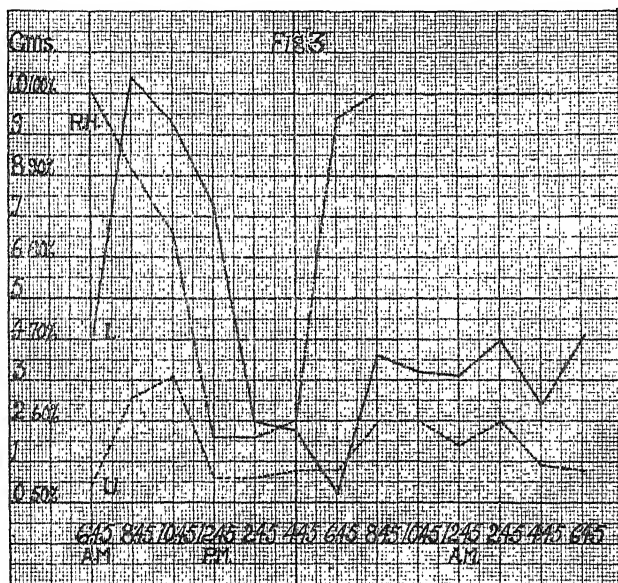
Fig. 3. Graph showing standard water loss for *Sambucus racemosa* during 24 hours. R. H., relative humidity. U, upper leaf surface. L, lower leaf surface.

water supply. The leaves were tagged and an area carefully marked on which the readings were taken each time. The readings were taken at two hour intervals. The results are graphically shown in Fig. 3.

Another series through 24 hours was obtained for *Catalpa bignonioides.* Readings were taken at intervals of 2 hours excepting from 7:45 A. M. to 3:45 P. M., during which time they were taken every hour. Five leaves, in apparently good condition, were selected and tagged as for *Sambucus.* Fig. 4 is a graph of the results obtained.

Peirce (14) states that many plants living in swamps and swampy places have constantly open stomata, and cites willows as a note-worthy example. Haberlandt (7) says "In many
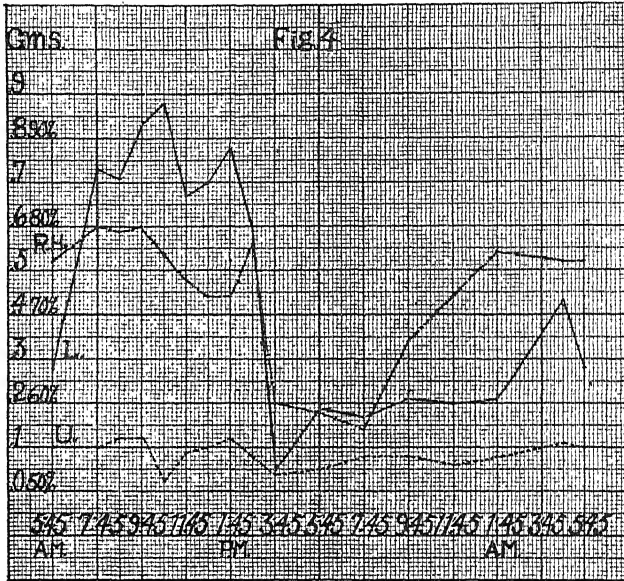
Fig. 4. *Catalpa bignonioides* standard water loss for 24 hours. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.
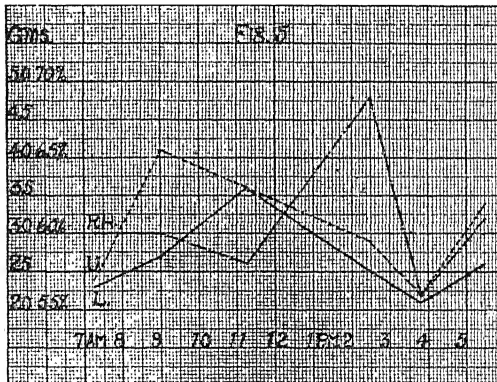
Fig. 5. *Polygonum amphibium* standard water loss. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.

plants the stomata lose their power of adjustment more or less completely, or at any rate become incapable of closing tightly after a certain age. This physiological degeneration of

the stomata takes place at a comparatively early age in floating and other aquatic plants, and also in a number of shade-loving hygrophytes.'' Delf (6) refers to such instances when considering Rosenberg's (15) work on the halophytes.

In order to investigate some of these aquatic and moist soil forms a series of readings were made, beginning first with *Polygonum amphibium*. The time of the readings range from 7:45 A. M. to 5:30 P. M., and were taken at two hour intervals.
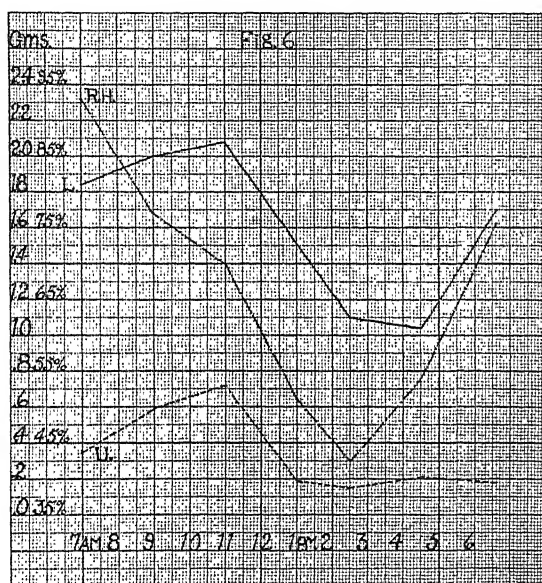
Fig. 6. *Salix nigra* standard water loss. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.

Fig. 5 shows the results. Series were taken on *Salix nigra*, *Dianthera americana*, *Hibiscus Moscheutos* and *Typha angusti-folia*. The *Salix* and *Dianthera* were growing in water along the edge of a river; and the *Polygonum Hibiscus* and *Typha* were growing in water along the edge of a Sphagnum bog. Figs. 6, 7, and 8 respectively show the results.

SUMMARY AND CONCLUSION.

1. The data collected on the list of plants holds good only for the time and conditions listed. The time of day, age of plant, position of leaves, and habitat have a great deal to do with the standard loss. Other unknown factors may also cause a variation.

2.   The average standard water loss for the whole list of 123 species, on which data was collected, is 1.15012 grams of water vapor in 1 hour for a leaf surface of 100 square centimeters. This and the following amounts are averages for both leaf surfaces.
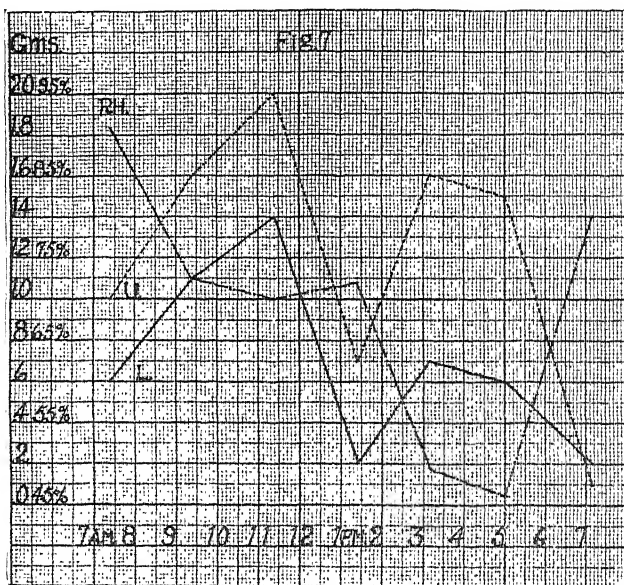
Fig. 7. *Dianthera americana* standard water loss. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.
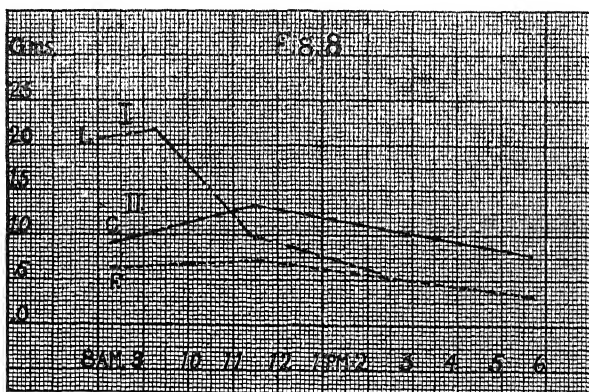
Fig. 8. I. *Hibiscus Moscheutos* standard water loss. Graph shows loss for lower surface only. II. *Typha angustifolia* standard water loss. C., curved surface. F., flat surface of leaves.

3. The average standard water loss, per hour for 100 square centimeters, for each group tested is as follows:

			No. Tested
I.	Spermatophytes..........	1.2146 gms.............	114
	A. Gymnosperms........	.605 gm.............	7
	B. Angiosperms..........	1.2545 gms.............	107
	1. Grasses*...........	.8256 gm.............	11
II.	Pteridophytes............	.4564 gm.............	7
III.	Bryophytes†............	4.571 gms.............	1

4. The average rate of standard water loss for each of 8 associations is as follows:

		No. Tested
Swamp...................	1.9644 gms............	10
Bog (acid)...............	.6413 gm.............	9
Pond and Lake Margin....	2.2965 gms............	4
River Margin............	1.9395 gm.............	3
River Bank....'.........	.9413 gm.............	3
Flood Plain (mature).......	.7549 gm.............	8
Ledge association..........	.293 gm.............	2
Talus slope..............	1.2218 gms............	8

5. The following plants showed the greatest standard loss:

Polytrichum ohioense........................4.571 gms.
Plantago major..............................3.802 "
Polygonum amphibium.......................3.661 "
Iris versicolor................................3.452 "
Alisma Plantago-aquatica....................3.267 "

6. The following is a list of plants showing lowest water loss:

Erigeron annuus‡............................ .04 gm.
Juglans nigra................................ .074 "
Bromus inermis.............................. .076 "
Elymus virginicus............................ .083 "
Buchloe dactyloides........................... .085 "
Silphium perfoliatum......................... .085 "
Aesculus glabra.............................. .09 "

7. Tests on evergreen leaves, before growth had started in the spring, showed the following results:

Angiosperms................................ .8523 gm.
Gymnosperms............................... .5481 "
Pteridophytes............................... .2401 "

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*This includes swamp as well as plain form).

†*Polytrichum ohioense*, growing in a very moist location.

‡This plant was growing in a very dry location. Tests were made on another plant growing at the edge of a swamp. The soil was very wet. The standard loss in this instance was .37805 gm. per 100 sq. cm.

8. Tests for comparison between *Acer saccharum*, *Pinus austriaca* and *P. sylvestris*, under apparently the same external environmental conditions, showed that the year old pine needles were losing more water than the leaves of the maple which were about 20 days old.

9. Tests on *Abutilon*, *Amaranthus*, *Chenopodium*, *Convolvulus*, *Digitaria*, *Setaria*, *Xanthium*, *Solanum* and *Zea*, all growing near one another in the same field, showed an average standard loss of 1.631 gms. The average for the weeds alone was 1.6485 gms. This includes *Digitaria* and *Setaria* which are very slow water losers. The average for the corn and potato was 1.5735 gms.

10. Graphic results of a series of readings on *Amaranthus* and *Zea*, growing side by side, shows that the pigweed loses nearly 6 times as much water as the corn per 100 square centimeters. This is just considering the maximum loss for each. The graph also shows that the time of maximum loss may vary for different species.

11. The following common "weeds," selected at random, showed an average standard loss of 1.1425 gms.: *Amaranthus*, *Xanthium*, *Chenopodium*, *Convolvulus*, *Abutilon*, *Lactuca*, *Arctium*, *Setaria*, *Digitaria*, *Taraxicum*, *Polygonum virginianum*, *Leonurus*, *Erigeron*, *Cirsium* and *Ambrosia*. Four agricultural plants showed a standard loss of 1.1085 gms. They were as follows: *Zea*, *Solanum tuberosum*, *Bromus* and *Phleum*.

12. Tests on rolled and unrolled leaves of *Elymus* showed that the unrolled leaves were losing over 10 times as much water as the leaves which were rolled.

13. Leaves of *Ulmus*, at an approximate altitude of 40 feet, were losing less water than those near the ground.

14. Very young leaves of *Silphium perfoliatum*, *Corylus*, *Arctium*, *Cephalanthus*, *Chenopodium*, *Convolvulus*, and *Sarracenia*, lose less water than mature leaves on which tests were made simultaneously. *Typha* showed a greater loss for the young leaves. The average standard loss for the group, including *Typha*, was 1.5735 grams for the young leaves and 1.8966 grams for the mature ones. In the instance of *Typha* the amount lost for the young leaves was 1.5825 grams per 100 square centimeters more than the total amount lost by the other seven species. Leaving *Typha* out of consideration, the mature leaves on the first seven species lost on an average of 3.916 times that of the young leaves.

15. A series of readings taken at different times during the spring, summer and autumn, on *Rosa*, *Catalpa*, and *Acer*, showed a decrease in the standard loss as the leaves grew older. At present the writer is unable to correlate these results with those obtained by simultaneous readings on young and mature leaves.

16. Young leaves of *Convolvulus*, *Psedera* and *Vitis*, showed a more rapid loss of water along the midrib and large veins than on other parts of the leaves. More mature leaves did not show this.

17. Series of readings running through 24 hours in the instances of *Catalpa* and *Sambucus*, and from 3 to 7 readings on *Polygonum amphibium*, *Salix nigra*, *Hibiscus*, *Dianthera*, *Typha angustifolia*, *Amaranthus* and *Zea*, showed that the maximum rate of water loss may occur at different times of day in different species. The series on *Polygonum*, *Salix*, *Hibiscus*, *Dianthera* and *Typha*, show that these water forms have a very decided rhythm in their water loss as do other forms tested, and that their rates of standard water loss varies within a wide range during the day.

18. More data, from many representatives of various groups and associations of plants, are needed before accurate generalizations can be made.

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NEW BOOKS.

A COMPREHENSIVE MEMORANDUM ON
SCIENTIFIC MANAGEMENT IN EUROPE

Has been issued as part of the documentation of the International Economic Conference, which began its sessions at Geneva on May 4. The document was prepared by the Economic and Financial Section of the League of Nations from information furnished to it by governments, by members of the Preparatory Committee for the Conference and by industrial organizations, which prepared memoranda at the request of members of the committee.

The salient phases of the subject and its international aspects are examined from this mass of information, and the statistical tables and summaries, as a consequence, are the most comprehensive, authentic and up-to-date available.

The memorandum is obtainable from the American agent for publications of the League of Nations, World Peace Foundation, 40 Mt. Vernon Street, Boston, Massachusetts. Price, $ .15.

REPORT OF THE THIRTY-EIGHTH ANNUAL MEET-
ING OF THE OHIO ACADEMY OF SCIENCE

The Thirty-eighth Annual Meeting of the Ohio Academy of
Science was held at the University of Cincinnati, Cincinnati.
Ohio, on Friday and Saturday, April 6 and 7, 1928, under the
presidency of Dr. Harris M. Benedict. Rarely if ever has a
meeting of the Academy been held in a more congenial atmos-
phere or under happier conditions, thanks to the untiring,
skillful efforts of President Benedict, who, at the risk of his own
health, ably assisted by an efficient local committee, and cor-
dially supported by the Mayor of the City, the President of the
University of Cincinnati, the Cincinnati Chamber of Com-
merce, and Hotel Alms, seemed to have left nothing undone for
the comfort and pleasure of the members of the Academy.

Among the special features provided for the entertainment
of the visiting members may be mentioned free admission to the
Cincinnati Art Museum, the famous Zoological Gardens, and,
by special arrangements, the celebrated Taft Collection of
Paintings; also permission to visit some of the larger factories
where one might see the practical applications of science in
industry; free transportation from Hotel Alms to the Univer-
sity and ample assistance in the matter of registration, informa-
tion, etc., by courtesy of the Chamber of Commerce; a specially
planned botanical field trip for Saturday afternoon under the
skillful leadership of Dr. E. Lucy Braun, to the "Prairie Open-
ings" at Miamiville and perhaps other points; a wealth of
beautiful flowers from the Federated Garden Clubs of the city;
and so on. It was indeed a joy and an inspiration to be there.

The banquet on Friday evening at Hotel Alms was undoubt-
edly the most largely attended and the most elaborate and
beautiful in the history of the Academy to date. "And thereby

hangs a tale." The "secret" almost leaked out! Rumor has it that at about this time the students of one of the most popular and highly esteemed professors at the University of Cincinnati were casting about for some appropriate way of manifesting their love and loyalty for their teacher. Hence the banquet "extras!" Lucky O. A. S. members! Congratulations, Mr. President, and hearty thanks to your students!

The central theme of the meeting—if there was a central theme—was "The Relation of Physics to Biology," as emphasized by the notable lecture and presence of Dr. William T. Bovie of the Northwestern Medical College, Chicago, probably the foremost authority on certain phases of protoplasmic response to physical force, and by other lectures and papers by eminent scientists, such as President Schneider's talk on results attained at the Basic Research Laboratory of the University of Cincinnati, Doctor Allen's lecture on the use of the X-ray as a means of investigating the structure of protoplasm, Doctor Mathews on the coagulation of the blood, and Mr. Kelly on "Recent Researches in Audition," etc.

The general program of the meetings was as follows:

FRIDAY, APRIL 6.

9:00 A. M.—Business meeting.
10:00 A. M.—Scientific lectures and papers in general session.
1:30 P. M.—Scientific lectures and papers in sectional meetings.
6:30 P. M.—Banquet Hotel Alms. Remarks by Mayor Seasongood.
8:00 P. M.—Invitation address by Dr. William T. Bovie, Northwestern University, Chicago, on "The Relation of Physics to Biology."

SATURDAY, APRIL 7.

9:00 A. M.—Scientific lectures and papers in sectional meetings.
11:00 A. M.—Invitation lecture in general session by J. B. Kelly, of the Bell Telephone Laboratories, New York City, on "Recent Researches in Audition."
11:45 A. M.—Adjourned business meeting.

MINUTES OF THE BUSINESS MEETINGS

The business meetings of the 38th Annual Meeting of the Ohio Academy of Science were held in the auditorium of McMicken Hall, University of Cincinnati.

The first meeting was held on Friday, April 6, 1928, and was called to order by President Benedict at 9:20 A. M. with about fifty members present.

The President announced the following committee appointments, viz.:

Committee on Membership—Charles H. Behre, Jr., E. Lucy Braun and Allyn C. Swinnerton.

Committee on Resolutions—L. B. Walton, Frederick C. Blake, and Emory R. Hayhurst.

Committee on Necrology—Herbert Osborn and A. E. Waller.

The reports of officers were then called for and the report of the Secretary and the report of the Treasurer were read, accepted and ordered filed.

The Academy then proceeded to the election of an *Auditing Committee* of two. Dr. A. Sophie Rogers and Dr. Frederick C. Blake were nominated and elected.

The reports of standing committees were then called for as follows: (a) The Executive Committee; report read by the Secretary. (b) The Publications Committee; oral report by E. L. Moseley. (c) The Trustees of the Research Fund; report read by the chairman, Dr. Herbert Osborn. (d) The Library Committee; the report of this committee was unusually elaborate and was presented by the chairman, Dr. F. O. Grover. An outstanding feature of this report was the presentation of a complete "List of Current Exchanges of The Ohio Academy of Science and The Ohio Journal of Science," prepared by Mrs. Ethel M. Miller. By a unanimous vote of the Academy it was decided to print in the Proceedings of this meeting a complete list of the current exchanges of The Ohio Academy of Science.

The President then called for the election by ballot of a nominating committee. The following were elected on said committee: L. B. Walton, J. H. Schaffner, A. C. Swinnerton, B. E. Neiswander, Samuel Renshaw, S. J. M. Allen.

At 10:10 A. M. the business meeting was adjourned to 11:45 A. M., Saturday, April 7, 1928, and the Academy went into general session, President Benedict presiding, to hear addresses and papers by President Herman Schneider, Dr. Samuel J. M. Allen, Dr. Albert P. Mathews and Mr. W. C. Devereaux.

The second business meeting was held as per adjournment on Saturday, April 7, 1928, and was called to order by President Benedict at 11:55 A. M.

The first item of business was the report of the Committee on State Parks and Conservation; the report was read by the Chairman, Dr. Herbert Osborn. Following the reading of this report, Doctor Osborn called the attention of the Academy to a Bill (H. R. 6091) introduced in the House of Representatives, 70th Congress, on December 7, 1927, by the Honorable John McSweeney, the preamble to which reads as follows:

A BILL

To insure adequate supplies of timber and other forest products for the people of the United States, to promote the full use of timber growing and other purposes of forest lands in the United States, including farm wood lots and those abandoned farm areas not suitable for agricultural production, and to secure the correlation and the most economical conduct of forest research in the Department of Agriculture through research in reforestation, timber growing, protection, utilization, forest economics, and related subjects, and for other purposes.

After some discussion. it was moved by Dr. R. C. Osburn and seconded by several that The Ohio Academy of Science endorse the Bill as introduced. The motion was unanimously and heartily passed and the Secretary was instructed to advise Congressman McSweeney of this action at once.

The reports of special committees were then called for and made as follows: (a) The Committee on the Election of Fellows; this report was read by the Secretary and appears elsewhere in these Proceedings. (b) The report of the Nominating Committee; this report was read by the chairman, Prof. L. B. Walton and is printed elsewhere in these Proceedings. (c) The Committee on Membership; this report was presented by the Secretary and appears elsewhere. (d) The report of the Committee on Necrology; a preliminary report was made by the chairman, Dr. Herbert Osborn, with the statement that a more complete report would be submitted for publication in these Proceedings. (e) The report of the Auditing Committee was read by the chairman, Dr. A. Sophie Rogers and is printed elsewhere. (f) Report of the Committee on Resolutions; this report was presented by the chairman of the Committee, Professor Walton, and appears elsewhere in these Proceedings.

The reports of all committees, both standing and special, were accepted and ordered filed.

Under new and unfinished business, it was unanimously voted:

(1) That the proposed amendment to Chapter 1, Section 1, of the By-Laws, recommended by the Executive Committee, be approved.

(2) That Dr. Herbert Osborn be the delegate of the Ohio Academy of Science to the International Congress of Entomology at Cornell University, August 12–18, 1928.

(3) That the printing of the list of members in full be omitted from the printed Proceedings for the year 1928 and instead a list of the newly elected members, resignations, and deaths during the past year be printed.

(4) That the appointment of a representative to the Council of the American Association for the Advancement of Science be left with the Executive Committee with power.

(5) That the time and place of the annual meeting in 1929 be referred to the Executive Committee with power.

(6) That the list of applicants for membership endorsed by the Executive Committee and presented by the Secretary, be elected.

The meeting adjourned at 1:00 P. M.

REPORTS

Report of the Secretary

CINCINNATI, OHIO, April 6, 1928.

To the Ohio Academy of Science:

The office of the Secretary has continued to function throughout the year and has earnestly tried to perform a useful, prompt service for the Academy and its 500 or more members, and in a broader way for all affiliated and co-operating orgnaizations of a similar character. While many members seem to have gotten along very nicely without making a single demand or request of the Secretary (fortunately for him, perhaps!), yet we are glad to report that the number of those willing to give the office a chance to serve them is on the increase.

As in other years, the first major task following the annual meeting of 1927 was the preparation of the proceedings and reports of the 37th Annual Meeting for publication. These appeared quite early in the summer as Part Two, Volume VIII, of the Proceedings of the Ohio Academy of Science. A brief summary of the meeting was also published in *Science* for May 27, 1927 (Vol. LXV, No. 1691). The 37th Annual Meeting was notable in that the attendance was large and an opportunity was given to hear two of the most distinguished scientists of the day, namely, Dr. Robert A. Millikan of the California Institute of Technology, and Dr. C. E. McClung, of the University of Pennsyl-

vania. The former discussed "Twentieth Century Discoveries in Physics," and the latter, "The Mechanism of Heredity." In addition to these two outstanding lectures, the members of the Academy prepared and presented some 81 papers on various topics; of these 81 papers, 10 were presented before the general sessions of the Academy, 11 before the section of Zoology, 19 before the section of Botany, 20 before the section of Geology, 11 before the section of Medical Science, and 10 before the section of Psychology. The section of the Physical Sciences and the Central Ohio Physics Club held two joint meetings, both of which were addressed by Doctor Millikan, the first on "The Birth of a Light Ray" and the second on "Relativity Inside an Atom."

In May of last year, under the fine leadership of Vice-President Swinnerton and Prof. Wilber Stout, some 45 members of the Section of Geology joined in a most interesting field trip into southern Ohio. Vice-President Swinnerton's report of this trip follows:

"The annual field trip of the geological section of the Ohio Academy of Science was conducted by Wilber Stout of the Ohio Geological Survey in the Portsmouth, Pomeroy region of southern Ohio on May 28, 29 and 30, with a registration of forty-five. The excursion was one of the most largely attended field trips in recent years of the section's activity.

"During the progress of the excursion, the party visited outcrops of the upper Waverlian Series of the upper Mississippian and the Pottsville, Conemaugh, and Monongahela Series of the Pennsylvanian, giving opportunity for both fossil collecting and stratigraphic study. The notable physiographic features of the region—the old Teays river valley, and other recently abandoned drainage systems, the upper Peneplain level, and the evidence for intermediate stages were examined by members of the party. Clay pits and mines were visited at Sciotoville, Scioto Furnace, and Oak Hill; near Jackson and Pomeroy, coal mines; and at Pomeroy, salt works. One of the most enjoyable features of the excursion was a starlight steamboat ride on the Ohio River at Pomeroy on the specially chartered 'Champion III.'

"Among the educational institutions represented were: Antioch College, Cincinnati University, Marietta College, Miami University, Muskingum College, Ohio Geological Survey, Ohio State University, Ohio Wesleyan University, and Toledo University.

A. C. SWINNERTON."

The Secretary represented the Academy at the Nashville meeting of the A. A. A. S. and was present at all the meetings of the Council, the latter part of December, 1927. In our report one year ago, mention was made of the temporary organization at the Philadelphia meeting of the A. A. A. S. in December, 1926, of the representatives of the affiliated academies. We now wish to report that a committee appointed by authority of this temporary organization, in co-operation with a committee appointed by the Executive Committee of the Council of the A. A. A. S., (Ward, Cattell, Livingston), the desirability of making such a meeting of the representatives of the affiliated academies a regular feature of the annual meetings of the A. A. A. S. was fully discussed during the year (1927) and the results are clearly stated in the following

letter from Dr. Burton E. Livingston, the Permanent Secretary of the A. A. A. S., to the Secretary:

WASHINGTON, D. C., January 12, 1928.

MR. WILLIAM H. ALEXANDER,
    16 E. Broad St., Columbus, Ohio.

DEAR MR. ALEXANDER:

This note is to give you official information of the action on academy relations taken by the Council of the American Association at Nashville. There are two minutes, as follows, of December 28, 1927:

"3. On recommendation by the Executive Committee, the Council adopted the following resolution:

"*Resolved:* That it is desirable to have at the annual meeting each year a conference of the representatives of the academies of science, this conference to be arranged by the Executive Committee of the Association.

"4. On recommendation by the Executive Committee, the Council recorded its approval of the officers of the academy conference named by the conference Monday afternoon, December 26: Chairman, W. H. Alexander; Secretary, H. E. Enders."

I think we have now clearly started on a program that will greatly improve the organization of American scientists. We look forward to great developments. The academy conference can well become a very important feature of the annual meetings and throughout the year.

I take it that the conference consists now of the representatives of the Executive Committee of the Association (Ward, Cattell, Livingston). Others may be added, I assume, by vote of the conference and approval by the Executive Committee of the Association, but such a body is more effective if not too large, as you know. It has been suggested that the academies be urged to name as their representatives men who will be active; this should not be regarded as a mere honor. We want people who will care and work. It is suggested also that the academy secretary is often the most suitable man for this work. If he is not available, then a past secretary (or at least a past president who has shown active interest) should be named.

I hope the new organization will soon become active. Anything we can do here, as in sending out circular letters, etc., we shall be glad to do. If you and Doctor Enders will take up and carry on correspondence with the other members of the conference, I am sure things will begin to develop. Please keep me informed and let me help where I can.

Yours very sincerely,

BURTON E. LIVINGSTON,
Permanent Secretary.

In this connection and at this time it may be proper to point out the fact that it will be the privilege and duty of the Academy at this meeting either to elect, or authorize the Executive Committee to appoint, a representative of this Academy on the Council of the A. A. A. S. for the New York meeting next December. Bearing on this matter of council representation the following quotation from a letter under date of February 7, 1928, from the Permanent Secretary may be of interest to the members of the Academy:

DEAR MR. ALEXANDER:

Your organization is affiliated with the American Association and has representation in the Association council and also in one or more section committees; representatives in the council are ex-officio members of the section committee to which their scientific work is most closely related or to which they are assigned by organizations. These members of the section committees are of course supposed to function throughout the year (as called upon by section secretaries, for advice, etc.), but I wish to call your attention to the desirability of appointing representatives of your organization for 1928 who will probably be present at the New

York meeting and who will not be too busy with other things. While the secretary of an affiliated society is logically perhaps the best man to represent a society, yet he is frequently too busy during the meeting to attend properly to his duty as a representative, and he is sometimes not present at the meeting

BURTON E. LIVINGSTON.

The Academy received a very gracious invitation from The Board of Directors and The Faculty of the University of Toledo to be present at the inauguration of Dr. Henry John Doermann as President of the University on March 19, 1928. With the approval of President Benedict, Dr. H. H. M. Bowman, fellow in this Academy and a member of the Faculty of the University of Toledo, was requested to serve as the official delegate of the Ohio Academy of Science and he consented to do so. Doctor Bowman's report follows:

TOLEDO, OHIO, April 2, 1928.

To The Ohio Academy of Science, William H. Alexander, Secretary,
    Columbus, Ohio:

On March 19, 1928, it was the peculiar privilege of the undersigned to represent the Ohio Academy of Science as its delegate at the inauguration of President Henry John Doermann, of the University of the City of Toledo. He is herewith acknowledging the honor of his appointment by the President of The Ohio Academy of Science and also submitting a brief report of the exercises as requested by the Secretary of the Academy. The ceremonies were held in the Toledo Museum of Art at which were present about 120 delegates of the colleges and universities and learned societies of the United States which had been invited. Together with these was a great throng of alumni, students, faculty, trustees and distinguished citizens of Toledo. The chief address of the occasion was given by President C. C. Little of the University of Michigan and the oath of office was administered by Federal Judge John M. Killits. The pleasant weather and the colorful academic costumes of delegates and faculty made the procession in the Art Museum plaza a picturesque spectacle. A copy of the program is inclosed for the Academy files.

In conclusion your delegate thanks the Academy for the honor it has conferred upon him in naming him as its representative on this pleasant occasion.

Very respectfully,

H. H. M. BOWMAN.

The Secretary is pleased to present to the Academy three invitations to hold the annual meeting in 1929, namely, Ohio Wesleyan University, Delaware, Ohio State University, and the Columbus Chamber of Commerce, Columbus, and Wittenberg College, Springfield.

The Secretary wishes before closing this report to call the attention of the members of the Academy to the highly efficient services of Mrs. Ethel M. Miller, who is so graciously and effectively serving the Academy as its librarian, handling all exchanges, looking after the sale of academy publications, including the Ohio Journal of Science, etc. On March 6, 1928, Mrs. Miller reported cash on hand from the sale of publications and other sources "nearly $300.00, divided about evenly between the Academy and the Journal." Thus by her own diligent efforts she has provided the money with which to pay the expense of printing Special Paper No. 20 by Prof. E. L. Moseley.

The membership list continues to grow, rather slowly to be sure, but nevertheless the gains exceed the losses, and we have now slightly more than 500 members, of whom about one-fourth are fellows. As shown elsewhere in these proceedings we have secured 51 new members and two reinstatements during the year.

A note of condolence was sent to The Royal Academy of Madrid, Spain, on the death of its President, His Excellency, Senor D. Jose Rodriguez Carracido, on January 3, 1928.

The four-page leaflet entitled "The Ohio Academy of Science," was revised and a supply printed.

<div align="center">Respectfully submitted,</div>

<div align="right">WILLIAM H. ALEXANDER, Secretary.</div>

Treasurer's Report for the Year 1927–1928.

RECEIPTS.

Cash balance on hand April 1, 1927	$ 491.34
Interest on Federal Land Bank Certificate	22.80
Dues from members, back dues collected	1,002.32
Total Receipts, Exhibit A.	$1,516.46

DISBURSEMENTS.

The Ohio State University Press for bookplate for gifts to the Library	$ 4.00
Schmitt Printing Co., 700 programs	33.75
W. H. Alexander, Secretary's honorarium	100.00
W. H. Alexander, Secretary's expenses for postage in connection with 1927 meeting	26.29
C. F. Wilson, Poster	2.00
W. G. Stover, postage, etc.	1.20
Helen Coleman, stenographic services	11.75
Schmitt Printing Co.	8.56
First-Citizens Corporation for accrued interest and balance of premium on hand Bank Certificate Purchase	24.25
Spahr & Glenn for printed statements	3.50
L. B. Walton, travel expense to attend Executive Committee meeting	4.72
Wm. H. Alexander, for secretary's expenses	19.25
Wm. H. Alexander, for secretary's expenses	19.00
Total Disbursements, Exhibit B	$258.21

Receipts	$1,516.46
Disbursements	258.21
Cash balance on hand April 1, 1928	$1,258.25

There are outstanding, however, several large items. Estimating these we have:

The Ohio Journal of Science for 1928	$ 650.00
Spahr & Glenn for three years Proceedings	200.00
Expenses of this meeting	150.00
Secretary's honorarium	100.00
Total	$1,100.00

or about $1,000 to be paid from the above balance. There are a few old accounts not yet collected and the allowance from the A. A. A. S. is payable during this spring. The treasury will therefore show a small but favorable balance. The money from the sale of publications is still being left in the hands of Mrs. Miller.

Report of the Executive Committee.

CINCINNATI, OHIO, April 6, 1928.

To the Ohio Academy of Science:

The Executive Committee held two meetings during the year, one on January 21, 1928, at Columbus, and the other last evening at Hotel Alms, in Cincinnati, Ohio.

At the first of these meetings, four of the five members were present, and by invitation two of the Vice-Presidents. The following items of business were presented, discussed and agreed upon:

1. The resignation of Prof. Alpheus W. Smith from the office of Vice-President of the Section of Physical Sciences was accepted with regrets and Dr. Frederick C. Blake was unanimously elected to fill the vacancy.

2. The Treasurer and Secretary were appointed a committee of two to draft and present at the next annual meeting of the Academy an amendment to Chapter I, Section 1, of the By-Laws, making the payment of dues in advance necessary to election to membership in the Academy.

3. The invitation from the University of Cincinnati to hold the annual meeting for 1928 in Cincinnati was unanimously accepted, the exact date of the meeting to be determined by President Benedict after a conference with the university authorities.

4. The selection and securing of an invitation speaker was left in the hands of the President. The names of Dr. W. W. Lepeschkin and Dr. William T. Bovie were suggested.

5. It was unanimously agreed that an invitation be extended through the President to the members of the Indiana and the Kentucky Academies of Science to attend our meeting in Cincinnati and present papers.

6. It was also voted to extend an invitation to the Natural History Club of the Ohio State University to make an exhibit of its rare collection of photographs, drawings, collections, etc. ·

7. Nine applications for membership in the Academy were unanimously approved.

8. The appointment by the President of Dr. Herbert Osborn, Dr. E. Lucy Braun and Mr. Arthur R. Harper as a sub-committee of the Standing Committee on State Parks and Conservation to co-operate with the State Forester in the formulation of rules and regulations for the protection of plant and animal life of the State Forests was announced.

9. The appointment of one or more delegates to the International Congress of Entomology to be held at Cornell University, Ithaca, N. Y., August 12–18, 1928, was left with the President and the Vice-President of the Section of Zoology.

At the second meeting of the Committee it was voted:

1. That the Executive Committee recommend to the Academy the consideration of the advisability of changing the date of the annual meeting to the last Friday and Saturday in February.

2. That the list of members be omitted from the published proceedings for the year 1928, and instead only the names of the new members, those who have resigned and those who have died during the past year.

3. That the fifty-one persons whose applications for membership in the Academy are on file with the Secretary be recommended for election to membership.

4. That the secretary be requested to secure further information relative to the problem of increased facilities for the encouragement of junior scientific effort and submit same with recommendation at the next meeting of the executive committee.

<div align="center">

Respectfully submitted,

THE EXECUTIVE COMMITTEE,

By WM. H. ALEXANDER, *Secretary.*

</div>

Report accepted and ordered filed.

<div align="center">

Report of the Trustees of the Research Fund.

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<div align="right">

CINCINNATI, OHIO, April 7, 1928.

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To the Ohio Academy of Science:

The additions to the research fund for the year, the balance of which was $120.41, have been: interest to the amount of $2.50 on June 3, and $48.00 on November 1, making a bank balance subject to check of $170.91. This, less $50.00 grant to Mr. B. G. Meyers, leaves a present bank balance of $120.91. Interest due this month will give us a bank balance of $170.91. Unless grants are made during the next three months it would seem advisable to deposit $100.00, which would increase our interest-bearing fund to $1500.00. At present our invested funds are: bonds $1300.00, certificate of deposit $100.00; total $1400.00

<div align="center">

SUMMARY.

</div>

Balance from last year	$120.41
Interest additions	50.50
Total	$170.91
Grant to Mr. Meyers	50.00
Balance subject to check	$120.91

Further funds due will permit grants during the year and the trustees will be pleased to receive suggestions as to the desirable use of the available amount.

Vouchers and certificate of invested funds are respectfully submitted.

<div align="right">

HERBERT OSBORN, *Chairman,*
For the Trustees.

</div>

Report of the Auditing Committee.

CINCINNATI, OHIO, April 7, 1928.

To the Ohio Academy of Science:

The Auditing Committee has examined the books of the Treasurer of the Academy for the years 1927 and 1928 and of the Trustees of the Research Fund for the year 1928, and find all accounts correct and all vouchers accounted for.

A. SOPHIE ROGERS, *Chairman,*
F. C. BLAKE,
Committee.

Report of the Committee on State Parks and Conservation.

CINCINNATI, OHIO, April 7, 1928.

To the Ohio Academy of Science:

The Committee feels that the matter of particular importance at present is the formulation of provisions for the care of the State Forests and Game Reserves, which, as announced yesterday, has been referred to a sub-committee to work with the authorities in charge of these tracts. We are encouraged by the interest in park and bird refuges, by different societies and individuals, and especially commend the efforts of the *Wild Flower Preservation Society* in its endeavors to secure greater protection to our native flora. We urge members of the Academy to work in their respective communities through schools, boy scouts, women's clubs, etc., and urge them to develop sentiment for the preservation of native fauna and flora.

Respectfully submitted,
HERBERT OSBORN, *Chairman,*
EMERY R. HAYHURST,
E. LUCY BRAUN,
E. L. FULLMER,
For the Committee.

Report of the Library Committee.

CINCINNATI, OHIO, April 6, 1928.

To the Ohio Academy of Science:

The allocation of exchanges among the Ohio Academy of Science, the Ohio Journal of Science and the Ohio State University Library has now been completed, the proper recognitions have been made by the Library, bookplates have been inserted in Ohio Academy volumes, and a card record has been prepared by the Accession Librarian for her files. Proper credit for future accessions will thus be assured. The utmost credit should be given to Mrs. Ethel M. Miller of the Botany-Zoology Library of the University for the completion of this important work.

The Committee recommends that the list of current exchanges received by the Academy be published in the next issue of the Proceedings.

One hundred and nineteen Academy publications have been sold to fifty-one individuals and institutions during the year. A statement of these sales is included in Mrs. Miller's appended report. The Chairman of the Committee has checked these sales and audited Mrs. Miller's books, and finds her accounts to be correct and her books to balance. The Committee urges the importance of a constant output of publications by the Academy. It believes that there should be at least one publication a year. The Committee recommends that the Academy approve the policy of financing one such publication each year.

Respectfully submitted,

F. O. GROVER, *Chairman*,
F. C. BLAKE,
E. L. MOSELEY.

*Report of Mrs. Miller for the Ohio State
Univesrity Library.*

COLUMBUS, OHIO, April 5, 1928.

To the Ohio Academy of Science:

The sales of the various publications of the Academy for the past year have amounted to $63.70. As the Treasurer of the Academy has allowed all sums accruing from sales since April, 1926, to remain on deposit, the bank balance is now $156.13.

The Proceedings of the Thirty-seventh Annual Meeting were received early in August and were mailed at once to 481 members, 90 exchanges and to 4 libraries which maintain standing orders for the publications of the Academy. This was an increase over last year of six exchanges and two standing orders.

The card catalog of the exchanges of the Ohio Academy of Science and the Ohio Journal of Science has been deposited in the Ohio State University Library. The Accession Department of the Library has also made a card for each exchange and these cards have been filed in the regular Order File in that Department. It is thought that this will eliminate the difficulties encountered heretofore in assigning the correct sources to the various books and periodicals which come as exchanges. It also gives the Accession Department a more complete record of the publications which come to the Library. Duplication of orders and exchanges will thus be avoided.

The card catalog shows what is sent from here for each exchange, whether Academy publications or the Ohio Journal of Science, the date and the volume with which each side began the exchange. In some cases, especially the foreign exchanges, it has not been possible to learn exactly the date of the beginning of the exchange, when it was before 1916. By far the larger number of the exchanges which have been secured was due to the untiring efforts of Mr. Reeder when he was

connected with the University Library.   He placed the exchange work upon a firm basis, and any work which has been done since he left the Library has been built upon the foundation which he laid.

In addition to the cards in the Order File and in the card catalog a list has been made of all the exchanges which come currently.   This list is arranged geographically and shows a number of interesting things, especially that there are some large cities and some important countries where there is not a single set of the Ohio Academy of Science Proceedings to be found.   This condition will likely exist as long as the Academy does not publish something regularly.

I am exceedingly glad that the publication of the Special Papers has been resumed.   I greatly hope that from now on at least one such paper may be published each year.   If the members will only furnish the papers, the sales of the publications can be expected to supply nearly half the amount needed for printing them, thus leaving not an excessive amount to be paid from the regular funds of the Academy.   Then more exchanges can be secured, more sales can be made and what is most important of all, the publications of the Ohio Academy of Science will compare more favorably with those of other Academies and learned Societies at home and abroad.

Very respectfully yours,

ETHEL M. MILLER.

LIST OF CURRENT EXCHANGES OF THE OHIO ACADEMY OF SCIENCE

Deposited in the Ohio State University Library.

Prepared by MRS. ETHEL M. MILLER.

(Exchanges marked with an asterisk (*) belong to both The Ohio Academy of Science and the Ohio Journal of Science.)

ARGENTINA

Buenos Aires.   Museo nacional de historia natural (*)
    Anales
Sociedad científica argentina (*)
    Anales
    Books

AUSTRALIA

Brisbane.   Queensland agricultural journal (*)

AUSTRIA

Vienna.   Naturhistorisches staatsmuseum (*)
    Annalen
Zoologisch-botanische gesellschaft(*)
    Abhandlungen
    Verhandlungen

BELGIUM

Brussels.   Académie royale des sciences, des lettres et des beaux-arts de Belgique (*)
    Annuaire
    Bulletins

BRAZIL

Sao Paulo.   Museu paulista
    Revista

CANADA

Ottawa.   Geological survey. (*)
    Annual report
    Bulletin
Quebec.   Quebec society for the protection of plants
    Report
Toronto.   University (*)
    Canadian historical review
    Studies

DENMARK

Copenhagen.   Danske videnskabernes selskab (*)
    Biologiske meddelelser
    Oversigt

ENGLAND

London.   British museum (Natural history)
Books
Guides
Insects of Samoa

FINLAND

Helsingfors.   Finska vetenskaps-societeten (*)
Acta societatis scientiarum fennicae
Arsbok-vuosikirja
Bidrag till kännedom af Finlands natur och folk
Commentationes biologicae
Commentationes humanarum litterarum
Commentationes physico-mathematicae
Societas pro fauna et flora fennica(*)
Acta
Acta botanica fennica
Acta zoologica fennica
Memoranda

FRANCE

Macon.   Académie de Mâcon (*)
Annales
Vesoul.   Société d'agriculture, lettres, sciences et arts du département de la Haute-Saône (*)
Bulletin

GERMANY

Berlin.   Universität. K. Zoologisches museum.
Mitteilungen
Berlin-Dahlem.   Germany. Biologische reichsanstalt für land- und forstwirtschaft (*)
Bibliographie der pflanzenschutz-literatur
Flugblatt
Nachrichtenblatt
Amtliche pflanzenschutzbestimmungen
Bremen.   Bremer wissenschaftliche gesellschaft (*)
Abhandlungen und vorträge
Books
Niederdeutsche zeitschrift für volkskunde
Frankfurt a M.   Senckenbergische naturforschende gesellschaft, Frankfurt am Main (*)
Bericht
Senckenbergiana
Stuttgart.   Verein für vaterländische naturkunde in Württemberg (*)
Jahreshefte

HAWAII

Honolulu.   Hawaiian entomological society (*)
Proceedings

INDIA

Madras.   Madras. Fisheries bureau
Bulletin

JAPAN

Sendai.   Saito ho-on kai (Saito gratitude foundation) (*)
Annual report
Monographs

MEXICO

Mexico.   Boletín oficial de la Secretaria de agricultura y fomento (*)
Dirección de estudios biológicos (*)
Boletín
Books

NORWAY

Tromso.   Tromso museum (*)
Aarsberetning
Aarshefter

PERU

Lima.   Sociedad geográfica de Lima (*)
Boletín
Universidad mayor de San Marcos
Anales de la Facultad de ciencias
Boletin bibliografico
Revista universitaria

PORTUGAL

Coimbra.   Sociedade broteriana
Boletim

SOUTH AFRICA

Kirstenbosch.   Botanical society of South Africa (*)
Journal
Report of National botanic gardens
Pretoria.   South Africa. Department of agriculture (*)
Bothalia
Journal
Publications, Division of botany, entomology

SPAIN

Barcelona.   R. Academia de ciencias y artes (*)
Memorias
Boletín
Club muntanyenc
Butlletí
Madrid.   Museo nacional de ciencias naturales (*)
Trabajos. Botánica, geológica, zoológica series

Flora iberica
Genera mammalium

SWEDEN

Upsala.   Universitet.   Mineralogisk-
geologiska institut (*)
Bulletin

UGANDA

Nairobi. East Africa and Uganda nat-
ural history society (*)
Journal

UNION OF SOCIALISTIC SOVIET
REPUBLICS

Tashkent.   Université de l'Asie cen-
trale (*)
Bulletin

UNITED STATES

ARIZONA

Flagstaff. Lowell observatory
Bulletin

CALIFORNIA

Berkeley.   California.   University (*)
Publications.   Agricultural sci-
ences, botany, geological sci-
ences, zoology
Claremont.   Journal of entomology and
zoology (*)
San Diego.   San Diego society of nat-
ural history (*)
Annual Report
Transactions
San Francisco.   California academy of
sciences (*)
Occasional papers
Proceedings
Terminal Island. California fish and
game commission.   State
fisheries laboratory.
Bulletin
Contributions
Report

COLORADO

Colorado Springs. Colorado college (*)
Publications. Language, science,
social science series

CONNECTICUT

Hartford. Connecticut. State geological
and natural history survey(*)
Bulletin
New Haven. Connecticut academy of
arts and sciences
Memoirs
Transactions

DISTRICT OF COLUMBIA

Washington. U. S. Department of agri-
culture (*)
Bulletin
U. S. Geological Survey (*)
Bulletin
Professional papers
Water-supply papers

ILLINOIS

Chicago. Chicago academy of sciences
Natural history survey bulletin
Field musuem of natural history (*)
Publications
Anthropological, botanical,
geological, report, zoological
series
Leaflets
Anthropology, botany, geol-
ogy, zoology departments
Rock Island. Augustana college and
theological seminary
Augustana library publications
Urbana. Illinois. Natural history sur-
vey (*)
Bulletin
Illinois. University (*)
Illinois biological monographs
Studies in language and literature

INDIANA

Brookville. Indiana academy of science
Proceedings

IOWA

Davenport. Davenport academy of sci-
ences (*)
Proceedings
Des Moines. Iowa academy of sciences
Proceedings
Sioux City. Wilson bulletin (*)

KENTUCKY

Lexington.   Kentucky   academy   of
science
Transactions

MASSACHUSETTS

Cambridge. Harvard university. Bus-
sey institution
Laboratory of entomology
Contributions
Harvard university.   Gray her-
barium (*)
Contributions
Memoirs
Woods Hole. Marine biological lab-
oratory (*)
Report

MICHIGAN

Ann Arbor. Michigan academy of science, arts and letters
    Papers

MINNESOTA

Minneapolis. Minnesota. University (*)
    Studies in the biological sciences

MISSISSIPPI

University. Mississippi geological survey
    Publications

MISSOURI

Columbia. Missouri. University (*)
    Studies
    Missouri. University. Observatory
    Publications
St. Louis. Academy of science of St. Louis (*)
    Transactions
    Missouri botanical garden (*)
    Annals

NEBRASKA

Lincoln. Nebraska academy of sciences
    Publications

NEW JERSEY

Princeton. Princeton university
    Contributions from the biological laboratories

NEW YORK

Brooklyn. Brooklyn institute of arts and sciences
    Botanic garden (*)
        Contributions
        Leaflets
        Memoirs
        Record
    Museum (*)
        Report
        Science Bulletin
Buffalo. Buffalo society of natural sciences
    Bulletin
New York. American museum of natural history
    Books
    New York academy of sciences (*)
        Annals
    New York botanical garden (*)
        Bulletin
Rochester. Rochester academy of science (*)
    Proceedings

OHIO

Cincinnati. University
    Studies
Cincinnati. Lloyd library of botany, pharmacy and materia medica (*)
    Bulletin
Granville. Denison university
    Scientific laboratories
        Journal
Oberlin. Oberlin college (*)
    Laboratory bulletin

OKLAHOMA

Norman. Oklahoma academy of science
    Proceedings

PENNSYLVANIA

Philadelphia. Academy of natural sciences of Philadelphia (*)
    Entomological news
    Proceedings
    Year book
    Wagner free institute of science of Philadelphia (*)
        Bulletin
        Transactions
Warren. Warren academy of sciences
    Transactions

SOUTH CAROLINA

Charleston. Charleston museum (*)
    Contributions
    Quarterly

SOUTH DAKOTA

Vermillion. South Dakota academy of sciences
    Proceedings

UTAH

Salt Lake City. Utah academy of sciences
    Transactions

VIRGINIA

Richmond. Virginia academy of science
    Proceedings

WASHINGTON

Seattle. Washington (State) University. Puget Sound biological station (*)
    Publications

WISCONSIN

Madison. Wisconsin academy of sciences, arts and letters (*)
    Transactions
Milwaukee. Public museum (*)
    Bulletin
    Year book

Report of the Committee on the Election of Fellows.

CINCINNATI, OHIO, April 6, 1928.

To the Ohio Academy of Science:

A meeting of the Committee on the Election of Fellows was held at Hotel Alms, Cincinnati, Ohio, on the evening of April 5, 1928, with a quorum of the Committee present, President Benedict presiding. Of the candidates nominated, six received the required number of favorable votes and were declared elected. In accordance with custom, the newly elected fellows will be personally notified, and their names will be published in the proceedings of this meeting.

WM. H. ALEXANDER, *Secretary,*
For the Committee.

The following is a complete list of those elected Fellows in the Ohio Academy of Science, viz.:

CHARLES HENRY BEHRE, JR.   KATHARINE DOORIS SHARP
FRED ANDREWS HITCHCOCK   JOHN PAUL VISSCHER
ROBERT ALLAN MOORE   FRANK J. WRIGHT

Report of the Nominating Committee.

CINCINNATI, OHIO, April 7, 1928.

To the Ohio Academy of Science:

Your Committee respectfully submits the following nominations for the offices mentioned, for the ensuing year:

President—JAMES S. HINE.
Vice-Presidents:
    Zoology—ANNETTE BRAUN.
    Botany—E. LUCY BRAUN.
    Geology—CHARLES H. BEHRE, JR.
    Medical Science—ALBERT P. MATHEWS.
    Psychology—SAMUEL RENSHAW. ·
    Physical Sciences—E. H. Johnson
Secretary—WILLIAM H. ALEXANDER.
Treasurer—A. E. WALLER.
Elective Members of the Executive Committee—R. C. OSBURN, STEPHEN R. WILLIAMS.
Trustee, Research Fund—GEORGE D. HUBBARD.
Publications Committee—F. O. GROVER, FREDERICK C. BLAKE, E. L. MOSELEY.
Library Committee—E. L. MOSELEY.
Committee on State Parks and Conservation—HERBERT OSBORN, ARTHUR R. HARPER, CONRAD ROTH.

L. B. WALTON, *Chairman,*
JOHN H. SCHAFFNER,
B. E. NEISWANDER,
ALLYN C. SWINNERTON,
S. J. M. ALLEN,
Committee.

Upon motion, the Secretary was instructed to cast the unanimous vote of the Academy for the above nominees which was done and they were declared elected.

Report of the Committee on Necrology.

CINCINNATI, OHIO, April 7, 1928.

To the Ohio Academy of Science:

During the past year the hand of death has fallen heavily on our Academy, since six of our eminent and beloved members have been called from our association. It is especially fitting that we give place in our proceedings to pay tribute to them and to express our sympathy to the families and friends of these departed comrades.

PROFESSOR BRUCE FINK.

Professor Bruce Fink, one of our most distinguished members and a Past President, died suddenly on July 10, 1927. He was born December 22, 1861, at Blackberry, Ill. He was educated in University of Illinois (B. S. 1894), Harvard (A. M., 1896) and University of Minnesota, (Ph. D., 1899). He was professor of botany at Upper Iowa University in 1902-03, professor of botany at Grinnell College from 1903 to 1906, when he came to Miami University. He was a member of Sigma Xi Research Fraternity; Fellow of the American Research Association for the Advancement of Science; member of the Society of Naturalists; member of the Society of Botanists of the Central States; Fellow of the Botanical Society of America; and member of the International Society of Botanists and Past President of the Iowa Academy of Sciences. He joined our Academy in 1906 and was President for the year 1912. He was an international authority on lichens, doubtless the leading one in America, if not in the world, and the author of many books and papers.

PROFESSOR WILLIAM CORLESS MILLS.

Professor Mills was born in Pyrmont, Ohio, January 2, 1860, and died January 17, 1928. He entered Ohio State University in 1881 but later studied in the Cincinnati School of Pharmacy, graduating in 1885. In 1897 he returned to Ohio State and received the Degree of Bachelor of Science in Agriculture in 1898 and the Master's degree in 1902. In 1898 he was made curator and librarian of the Ohio Archaelogical and Historical Society and in October, 1921, he was made Director of the Museum, a position occupied until his death. He joined the Academy in 1898 and was elected a Fellow in 1920 and served as Chairman of the Library Committee from 1916 to 1924.

Professor Mills was a man of very genial character and had a host of friends throughout the state and among the archaeologists of the country. He was an ardent and very successful collector especially of the Indian relics of the Ohio Mounds and has published many papers upon this subject. He was expert in the preparation and exhibition of material and the Archaeological Museum is a permanent tribute to his skill.

PROFESSOR GEORGE H. COLTON.

Professor Colton was born in Nelson, Portage County, Ohio, on October 10, 1848, and died June 4, 1927. He graduated from Hiram College in 1871. He taught a wide range of subjects: Geology, Physics, Chemistry, Physical Geography, Biology, Anatomy, Zoology, Physiology, and perhaps other subjects. He joined the Academy in 1892 very soon after its organization and maintained his membership throughout the remaining years of his life.

JOHN W. SCHAEFFER.

Mr. John W. Schaeffer, of the Columbus Weather Bureau Station, died suddenly on October 10, 1927. He was born March 18, 1858, at Troy, Ohio. Mr. Schaeffer enlisted in the Signal Corps on October 24, 1887, and served continuously, his longer assignments being Des Moines, Milwaukee, Ithaca and Columbus. His service in the last-named place totaled nearly 18 years. He joined the Academy in 1927.

EBEN HUTCHISON EMERY.

Mr. Emery was born in Athens, Maine, on December 8, 1860, and died March 12, 1928. He entered the United States Weather Bureau 44 years ago and was eminent in the service, holding the important position of chief of the Cleveland Station since 1916. He has been a member of the Academy since 1921.

RALPH LUSK.

Mr. Ralph Lusk was born in Manchester, Iowa, July 14, 1896, and died July, 1927. He received the degree of Bachelor of Science from Denison University in 1922 and attended Chicago University 1922-'23 and served as Field Assistant of the United States Geological Survey 1922-'23 and as Junior Geologist in 1924. He was an instructor of Geology in Denison University in 1923-'24, and Assistant in Geology at Harvard University for 1924-'25, Austin teaching fellow 1925-'26, instructor in 1926-'27. He also served as Field Geologist on the Tennessee Geological Survey in 1925-'26. He became a member of the Ohio Academy of Science in 1924.

JACOB LOWELL ROUDEBUSH.

Mr. Roudebush was born March 6, 1852, and died December 11, 1926. He attended Holbrook Normal School at Lebanon, largely self-taught, and was an enthusiastic agriculturalist, delivering many lectures on agricultural chemistry, soil fertility and entomology. He was a distinguished citizen of Clermont County, fearless in action, forceful as a speaker, up-to-date as a farmer, scholar and student. Mr. Roudebush joined the Ohio Academy of Science in 1900, was a member of the State Horticultural Society, and a fellow in the National Geographic Society.

We recommend that this memorial notice be incorporated in the minutes of the Society and published in the Proceedings.

HERBERT OSBORN,
ADOLPH E. WALLER,
Committee.

Report of the Committee on Resolutions.

CINCINNATI, OHIO, April 7, 1928.

The Ohio Academy of Science wishes to express its hearty appreciation to the following organizations and individuals for the co-operation which has made the thirty-eighth annual meeting one of the most enjoyable assemblages of the Academy:

1. To the members of the Local Committee whose responsibility has been that of the general arrangements.

2. To the Cincinnati Chamber of Commerce for the excellent provisions made in connection with registration and transportation and for the young ladies who rendered such helpful assistance.

3. To the authorities of the University of Cincinnati for the use of its buildings and equipment.

4. To the Federated Garden Clubs of Cincinnati for the floral decorations so generously supplied for the banquet tables and through which their cordiality to the Academy was so beautifully expressed.

5. To the management of Hotel Alms for various courtesies so cordially extended.

6. To Dr. William T. Bovie, of Northwestern University, and to Mr. J. B. Kelly, of the Bell Telephone Laboratories of New York, for the educational entertainment afforded by their lectures.

7. To Dr. A. E. Waller, Mr. Robert B. Gordon, Mr. Arthur R. Harper, Mr. Edward S. Thomas and Mr. Roscoe W. Frank for the interesting exhibit of natural history, photographs, etc.

8. And particularly to our President, Dr. Harris M. Benedict, for his most successful efforts in providing for the comfort of the members and the welfare of the Academy.

Respectfully submitted,

L. B. WALTON, *Chairman,*
F. C. BLAKE,
EMERY R. HAYHURST,
Committee.

Report unanimously approved.

List of Withdrawals.

AINSLIE, GEORGE G................................Knoxville, Tenn.
ARNOLD, H. J...Springfield
BEAM, J. ALBERT...Tiffin
BEARSS, ESTHER..........................Sulphur Springs, Fla.
BOHSTEDT, G...Wooster
BUSCH, K. G. A...Columbus
CAMP, MRS. JEAN TURNER..............................Westerville
CAMPBELL, EVA G......................Guilford College, N. C.
CASKEY, M. W...................................Louisville, Ky.
EASTERLING, G. R...Athens
ELIOT, THEODORE S.....................................Cleveland
FEARING, FRANKLIN.....................................Delaware
FORDYCE, GEORGE L..................................Youngstown
GILMORE, GRACE...Wooster
HANSEN, WALTER...Oberlin

HARP, HUGH G..Springfield
HURST, MACLEOD E....................................Columbus
JOHNSTON, WILLIAM D...........................Socorro, N. M.
JONES, EDWARD S..................................Buffalo, N. Y.
KUECHLE, THEODORE FRED............................Columbus
MADISON, HAROLD L..................................Cleveland
MORE, LOUIS T.....................................Cincinnati
PETTIJOHN, FRANCIS J..........................St. Paul, Minn.
SCHRADIECK, JACOB E...........................:...Baltimore, Md.
SETTERFIELD, HUGH..................................Columbus
SOUTH, EARL B.................................Albany, N. Y.
TRIESCHMANN, JACOB E..........................Evanston, Ill.
TUTTLE, W. W...................................Iowa City, Ia.
UNNEWEHR, EMORY C.............................St. Paul, Minn.
YOUNG, R. A...................................Gainesville, Fla.

List of Deceased Members.

COLTON, GEORGE H.......................................Hiram
EMERY, E. H..Cleveland
FINK, BRUCE...Oxford
LUSK, RALPH G......................................Granville
MILLS, W. C...Columbus
ROUDEBUSH, LOWELL...............................New Richmond
SCHAEFFER, JOHN W..................................Columbus

List of New Members.

The following is a list of the persons whose applications for membership in the Academy were favorably passed upon by the Executive Committee or the Membership Committee and whose election to membership was unanimously approved by the Academy:

ARGO, VIRGIL N., Department of Entomology, O. S. U., Columbus. (Entomology).
*AUTEN, (MISS) MARY, Ohio Northern University, Ada. (Zoology; Entomology; Botany).
AYRES, DR. WYLIE MCL., The Groton Bldg., Seventh and Race Sts., Cincinnati. (Botany; Medical Sciences).
BARKER, CHARLES A., 1017 Cumberland Ave., Dayton. (Psychology).
BARR, DR. DANIEL R., Box 137, Grand Rapids, Ohio. (Physiology of Circulation. General Science as a matter of general interest).
BERGNER, SELMA RUTH, 220 Stanton Ave., Springfield. (Biology).
BITTER, MYLDRED L., 41 West College Ave., Springfield. (Biology; Zoology; Medical Sciences).
BOETTICHER, A. W., Ohio University, Athens. (Biology; Botany).
BOWE, LULU, 220 Stanton Ave., Springfield. (Zoology; Medical Sciences).
BROWER, A. B., 700 Fidelity Bldg., Dayton. (Medical Sciences).
CANOWITZ, AARON SIMPSON, 744 S. 18th St., Columbus. (Medical Sciences; Physiology; Pathology).
DE GANT, FRANK D., 3401 Wade Ave., Cleveland. (Entomology; Esp. External Anatomy).
DENNIS, (MRS.) MARSENA ANNE, 125 Euclid Ave., Marietta. (Botany; Zoology).
DORST, STANLEY E., Department of Medicine, Cincinnati. General Hospital, Cincinnati. (Medical Sciences).
ENGLISH, HORACE B., Antioch College, Yellow Springs. (Psychology).
EVERLY, RAY THOMAS, 1470 S. High St., Columbus. (Entomology; Botany).
FILINGER, GEORGE A., Ohio Agricultural Experiment Station, Wooster. (Entomology; Horticulture).
GAHM, O. E., 151 W. 11th Ave., Columbus. (Entomology; Plant Pathology).

' Reinstatement.

GASKILL, H. V., 1718 Bryden Road, Columbus. (Psychology).
GEIST, ROBERT M., 811 Euclaire Ave., Columbus. (Entomology; Ornithology; Zoology).
GOLDSTEIN, SAMUEL, 414 S. Monroe Ave, Columbus. (Medical Sciences; Physiology; Pathology).
HAMLIN, HOWARD ELROY, Hamilton Hall, O. S. U., Columbus. (Medical Sciences; Botany; Zoology).
HAPPER, MARY LOUISE, 1840 Crescent Drive, Springfield. (Medical Sciences; Bacteriology).
HORTON, CLARK W., Botany Department, O. S. U., Columbus. (Botany).
*JOHNSON, E. H., Kenyon College, Gambier. (Physical Sciences).
JOHNSTON, EARL N., 18 Main St., Easthampton, Mass. (Zoology; Botany).
KOFFEL, GERALD LOWELL, 1110 Sixth St., N. W., Canton. (Biology; Entomology).
KRUEGER, LILLIAN K., 548 Colburn St., Toledo. (Botany).
LEATHERMAN, GLADYS A., 227 W. Pleasant St., Springfield. (Zoology; Physiology).
MCLAUGHLIN, GEORGE D., University of Cincinnati, Cincinnati. (Bacteriology; Chemistry).
MILLER, RALPH L., Department of Zoology, O. S. U., Columbus. (Entomology; Zoology; Botany).
MORGAN, RICHARD, 1610 Hunter Ave., Columbus. (Geology).
NEISWANDER, BYRON E., 1286 Primrose Place, Columbus. (Medical Sciences).
NEWHALL, A. G., Ohio Agricultrual Experiment Station, Wooster. (Botany; Plant Pathology; Plant Physiology).
NICE, LEONARD BLAINE, Hamilton Hall, O. S. U., Columbus. (Medical Sciences; Zoology; Botany).
PEW, DAVID R., Miami University, Oxford. (Zoology; Anatomy).
RIDLEY, LENDELL CHARLES, Wilberforce University, Xenia. (Psychology).
SAVAGE, JOHN R., Ohio Agricultural Experiment Station, Wooster. (Entomology; Zoology; Ecology).
SEGELKEN, JOHN G., 2321 W. McMicken Ave., Cincinnati. (Botany).
SEMANS, FRANK M., 1690 Merrick Road, Columbus. (Zoology; Botany).
SIMPSON, DR. WALTER, Miami Valley Hospital, Dayton. (Medical Sciences; Pathology).
SITTLER, MARGARET, 115 E. Mulberry St., Lancaster. (Zoology).
SLAGG, RODNEY A., 433 E. Buchtel Ave., Akron. (Botany; Geology).
SPRAGUE, RODERICK, Department of Botany, Univeristy of Cincinnati, Cincinnati. (Botany; Plant Pathology).
TASHIRO, SHIRO, Medical College, University of Cincinnati, Cincinnati. (Medical Sciences; Chemistry).
THEIS, CHARLES V., Department of Geology, University of Cincinnati, Cincinnati. (Geology).
UPHAM, J. H. J., 327 E. State St., Columbus. (Medical Sciences).
VON SCHLICHTEN, OTTO C., University of Cincinnati, Cincinnati. (Geology).
WALKER, MARY ELIZABETH, 294 King Ave., Columbus. (Zoology; Entomology; Bacteriology).
WESTENBARGER, MARY ELLEN, Magnolia, Ohio. (Zoology; Embryology).
WHERRY, W. B., 759 Ridgeway Ave., Cincinnati. (Medical Sciences).
WHITE, MONICA, 100 Center St., Struthers, Ohio. (Zoology; Botany).
WOZENCRAFT, PAUL, U. S. Weather Bureau, Columbus. (Physical Sciences; Psychology).

A CORRECTION.

In some curious way the name of Mr. August E. Miller has never appeared in the list of members of the Academy. It should have appeared in the Proceedings of 1926, both in the list of new members and in the complete membership list as follows:

'26 MILLER AUGUST E.; *Entomology*.....................Urbana Ill.

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* Reinstatement.

THE SCIENTIFIC SESSIONS.

The following is a complete scientific program of the meeting:

PUBLIC LECTURES BY INVITATION SPEAKERS.

The Relation of Physics to Biology...................DR. WILLIAM T. BOVIE
The Use of the X-ray as a Means of Investigating the Structure of Protoplasm,
DR. SAMUEL J. M. ALLEN
Recent Researches in Audition................................J. B. KELLY

PAPERS.

(Numbers in parenthesis after the title refer to abstracts).

1. Results from the Basic Research Laboratory of the University of
   Cincinnati...............................PRESIDENT HERMAN SCHNEIDER
2. Some aspects of the problem of coagulation of the blood,
   DR. ALBERT P. MATHEWS
3. Progress in practical meteorology (42)...................W. C. DEVEREAUX
4. The sessile flora and fauna of Norfolk Harbor in relation to the problems
   of fouling of ships' bottoms........................J. PAUL VISSCHER
5. Notes on the millipede Cleidogona caesioannulatus Wood...S. R. WILLIAMS
6. Studies on the anatomy and histology of the alimentary canal of Euryurus
   erythropygus Brandt, a polydesmid millipede...........HUGH H. MILEY
7. A study of the Ohio species of vespertilionidae............JAMES S. HINE
8. Fowler's Toad, Bufo fowleri, in Ohio.................EDWARD S. THOMAS
9. Seven new mutants in Droophila funebris and their mode of inheritance,
   WARREN P. SPENCER
10. The development of the external sexual structures of Paraiulus venutus,
    Wood...R. A. HEFNER
11. The vegetation of Hungary and Roumania...............E. N. TRANSEAU
12. Seasonal variations in the osmotic value of the leaf tissue fluids of the
    Pitch Pine..B. S. MEYER
13. A new high record of the lifting of water in enclosed tubes by the energy
    of evaporation.......................................HIRAM THUT
14. The genus Ascochyta of the sub-family Papilionideae of the Leguminosae,
    RODERICK SPRAGUE
15. The production of completely neutral or sterile tassels in Indian corn,
    J. H. SCHAFFNER
16. Rare Teleutospores in rye rust...............................O. L. INMAN
17. The distribution of corn and some of its relatives in the light of recent
    archeological discoveries...............................A. E. WALLER
18. The behavior of corn under artificial light. (Introduced by A. E. Waller),
    GRACE COLLET
19. The Hazelwood Botanical Preserve.....................JOHN G. SEGELKEN
20. Educating the public................................KATHARINE D. SHARP
21. The floristic regions of Ohio (1)........................ROBERT B. GORDON
22. Plans for the spring field trip of the Section of Geology of the Ohio
    Academy of Science. (2)............................A. C. SWINNERTON
23. Quantitative vs. qualitative observations in Geology. (3)...GEO. D. HUBBARD
24. The newer aspect of crystallography. (4)............O. C. VON SCHLICHTEN
25. The petrography of some slates. (5)...................C. H. BEHRE, JR.
26. Apparent orthogenesis in the genus spirifer. (6)......CARROLL LANE FENTON
27. The affinities of the true stromatoporoids. (7).......GEORGE B. TWITCHELL
28. Nature and relationships of the genus aulopora. (8)..MILDRED ADAMS FENTON
29. Recurrent faunas in the Cincinnatian (9a).................W. H. SHIDELER
30. A re-study of the Hamburg, Indiana, Section. (9).........W. H. SHIDELER
31. The occurrence of marine faunas during Richmond Times in more or
    less distinct provinces; the location and significance of these provinces,
    AUG. F. FOERSET
32. The geology of Lucas County, Ohio. (10)...............J. ERNEST CARMNA

78. Multiple myeloma. (32),
                    KARL D. WAY, DR. F. M. STANTON AND DR. ERNEST SCOTT
79. The histogenesis of malignant mesenchymal tumors of the kidney. (33),
                                                    BERNARD E. INGMIRE

DEMONSTRATIONS AND EXHIBITS.

1. Core samples from salt dome cap rock...................WALTER H. BUCHER
2. Structural features of slates............................C. H. BEHRE, JR.
3. An exhibit of over 200 photographs (enlargements) by the Natural History Club, Ohio State University, Columbus, showing native Ohio mammals, reptiles, birds, nests and eggs, wild flowers, ferns, and fungi, in their natural surroundings, as well as several choice Ohio landscapes,
                                              ROSCOE W. FRANKS, in charge
4. Drawings of Hawaiian dragonflies..................CLARENCE H. KENNEDY

ABSTRACTS
OF
SCIENTIFIC PAPERS AND DISCUSSIONS AT THE CINCINNATI MEETING, APRIL 6 AND 7, 1928.

All members of the Academy taking part on the several programs of the 38th Annual Meeting at Cincinnati, either in the presentation of a paper or in the oral discussion that followed, were asked to prepare abstracts of their papers or remarks for publication in these Proceedings. This being in the nature of an innovation, the response has been quite gratifying and we are pleased to present the following outlines by the authors themselves. A few abstracts were received too late to be classified and were therefor put at the end of the list.

A. THE SECTION OF ZOOLOGY.
ARTHUR W. LINDSEY, Denison University, *Vice-President*

B. THE SECTION OF BOTANY.
HOMER C. SAMPSON, Ohio State University, *Vice-President*

1. The Floristic Regions of Ohio.
By ROBERT B. GORDON, Ohio State University, Columbus, Ohio.
(Author's Abstract).

Due to the influences of the last glaciation, and the subsequent migration of the deciduous forest into this state, over one hundred species of the northern flora are found as relicts in sphagnum bogs and in deep gorges throughout the State of Ohio, but are much more abundant

in the northeastern corner, where forests containing hemlock, white pine, and tamarack have in some cases developed and have persisted to the present time.

Forty-five species of plants, including *Andropogon furcatus* and *Silphium terebinthinaceum*, typical of the prairies, are found in Ohio, chiefly in regions where the forest is oak and oak-hickory. Over half of these species reach their eastern limit in Ohio. They are thought to have invaded the state during the xerothermic period which began well after the retreat of the glacier.

Some sixty species of plants, including *Castanea dentata* and *Magnolia acuminata*, are confined to the Allegheny Plateau in Eastern Ohio, extending northward to Lake Erie. It is in this region that mixed mesophytic forests occur.

Fifty species of plants, including one of the southern pines, *Pinus echinata*, are limited to the unglaciated portion of southern Ohio. Most of these are upland species which have apparently migrated northward along rock cliffs and high-level terraces of the old pre-glacial Teays River System from localities near its source in the northern Blue Ridge Mountains, where they were evidently distributed at the time of maximum glaciation.

The four regions thus outlined in Ohio may be called respectively, the Northern Floristic Region, the Prairie-Oak Floristic Region, the Allegheny Plateau Floristic Region, and the Southern Appalachian Floristic Region.

C. SECTION OF GEOLOGY.

ALLYN C. SWINNERTON, Antioch College, *Vice-President*.

2. *Plans for the Spring Field Trip of the Section of Geology, Ohio Academy of Science.*

By ALLYN C. SWINNERTON, Antioch College, Yellow Springs, Ohio.

(Author's Abstract).

It is planned to hold the 1928 spring field trip of Ohio geologists in the region of the Bellefontaine outlier (Devonian) and the Silurian and uppermost Ordovician near Springfield and Dayton. The time of the excursion is set for June 1st, 2nd, and 3rd.

The party will assemble at 10:00 A. M., June 1st, at the Ohio Caverns near West Liberty. After a trip through the cave the remainder of the day will be spent in a study of the Bellefontaine area under the direction of Professors J. Ernest Carman and C. F. Moses. On June 2nd the quarries in the vicinity of Springfield, Cedarville, and Osborn will be visited under the guidance of Dr. Aug. F. Foerste. The evening of June 2nd will be spent in Dayton where the group will be addressed by Arthur E. Morgan, president of the Dayton-Morgan Engineering Co., on the subject of the Miami Conservancy District. The following day will be spent in studying, under Dr. Foerste's direction, the Silurian of the Dayton region.

3. Quantitative vs. Qualitative Studies in Geology.

By GEORGE D. HUBBARD, Oberlin College, Oberlin, Ohio.

(Author's Abstract).

Geologists have ever studied and measured geologic processes and accomplishments, relatively, but it is time for us to do many phases of our work in a more quantitative way.

We can measure the rate of stream erosion by getting, for given time periods, the change in size and form of valleys. This should be done in many valleys. By careful measurements at the beginning and end of time periods we can get a rate of wave erosion and a rate of wave deposition. By measuring many waterfalls, each under different conditions, we can get a rate for fall recession. Rate of sedimentation can be gotten in lakes, in marshes, and possibly in shallower sea areas, and the rate of growth of deltas can be obtained by two accurate surveys separated by a considerable unit of time. Such measurements would not necessarily give us a key to geologic time but they would give us data concerning the actual present rate of geologic activities, and at the same time a better basis for estimating ancient rates of processes and of calculating geologic periods. The completed paper recognizes several pieces of quantitative measurement but the abstract could not note them.

4. The Newer Aspect of Crystallography.

By OTTO C. VON SCHLICHTEN, University of Cincinnati, Cincinnati, Ohio.

(Author's Abstract).

With but little modification Hauy's hypothesis, that crystals are built up of parallelopipeds, all of the same shape and dimensions for any given crystal, holds good at the present day. This hypothesis was formulated during the latter part of the eighteenth century. Later Bravais showed that only 14 different kinds of such parallelopipeds or space lattices could exist and these had the characteristics of crystal symmetry but were restricted to the symmetry of the holohedral classes of the seven crystal systems. Hessel, and later Gadolin, showed that 32 crystal classes could theoretically exist consistent with the law of rationality of parameters. In 1891 Schoenflies demonstrated that 230 kinds of point arrangements are possible and that these groups would fall within the 32 classes referred to. Whether these points were atoms, molecules or aggregates of molecules was not known with certainty but it was held by Groth that they were the atoms themselves.

In 1912 Dr. Laue, of Zurich, a former student of Groth, conceived the idea that the regularly arranged points of a crystal might be used as a three dimensional diffraction grating, as it was then believed that if X-rays represented a wave phenomenon the wavelengths must be of the order of the spacings of the atoms in solids. His conjecture was verified and thus a means was afforded to make precise measurements of the spacings between the atoms in crystals, to determine the shape and dimensions of the space lattice, and the number, position and kind of atoms within the lattice. Thus in this newer aspect of crystallography a powerful method was developed to greatly extend our knowledge of the ultimate constitution of solid matter.

5. *The Petrography of Some Slates.*

By CHARLES H. BEHRE, JR., University of Cincinnati, Cincinnati. Ohio.

(Author's Abstract).

Certain minerals growing during contact or dynamic metamorphism do not orient themselves with regard to maximum stress; these are "metacrysts." Examples are garnet, staurolite, chiastolite, and some chlorites. Secondary chlorite crystals in Ordovician slates of Pennsylvania, and chiastolite crystals induced by contact metamorphism in the English Skiddaw slates have this feature in common. Both show effects of subsequent deformation—the chiastolite by distorted form, the chlorite in alteration to tertiary muscovite. By analogy with the Skiddaw slates, therefore, the Pennsylvania slates have been twice deformed. This feature is cited as an illustration of the structural interpretation of metamorphic minerals.

Distinction is also made between "fracture cleavage" and "grain" in slate—terms generally regarded as roughly synonymous. "Grain" is probably present to varying extent in all mica slates, and is due to parallelism in the longer dimensions of mica flakes in the rock. "Fracture cleavage," however, is only anticipated in those slates which were folded after the development of secondary minerals. Slates, unlike shales, generally yield like brittle materials; they have their mica flakes at first bent, but soon broken, with very small-scale faulting, giving the "fracture cleavage" already recognized by several geologists.

6. *Apparent Orthogenensis in the Genus Spirifer.*

By CARROLL LANE FENTON, University of Cincinnati, Cincinnati, Ohio.

(Author's Abstract).

The group of late Devonian brachiopods characterized by the forms generally called *Spirifer orestes* H. & W. show numerous examples of apparently orthogenetic evolution. In each of the several lines or gentes composing the group, there is a marked progression from wide, thin shells with strong plications to narrow, gibbous ones in which the plications are weak. There also is a progression from shell ornament consisting of striæ, through nodose, broken striæ, to ornament of pustules which ultimately lose all trace of linear arrangement. To a considerable extent these sequences are correlated, and they may be traced in the ontogeny of gerontic specimens.

The fact that the changes appear at various times in various lines shows that they are not caused by progressive environmental change; and there is no evidence that the characters possess selective value. So far as can be determined, each evolutionary step is discrete, and possesses the character of a Morganian mutation.

To explain the regularity of the sequences, the hypothesis of advancing racial senescence is advanced. It is supported by the nature of the changes, which are distinctly degressive, and by the fact that ultimate stages in either sequence (of shape or ornament) are followed by extinction in several of the gentes.

7. *Affinities of the True Stromatoporoids.*

By GEORGE B. TWITCHELL, M. D., Cincinnati, Ohio.

(Author's Abstract).

M. Heinrich (Journ. Geol., Vol. 24) selected from the genera of the stromatoporoids a natural group consisting of *Clathrodictyon, Actinostroma, Stylodictyon, Parallelopora, Stromatopora* and *Stromatoporella. Hermatostroma* is doubtfully included.

These true stromatoporoids show one general plan of structure. They are made up of several layers or lamellæ. Each layer consists of several biological units arranged in one plane, and known as astrorhizal systems. An astrorhizal system communicates with the outer world by an opening at its centre, from which radiate branching canals, whose ultimate ramifications are in connection with those of adjoining units.

Systems in the several layers may be superimposed, communicating with one another by means of a central opening or astrorhizal cylinder. When they are not superimposed, connection between systems in different layers is effected by large arms of the astrorhizal system.

Laminæ are connected by pillars; the open spaces between these pillars are the ultimate ramifications of the astrorhizal tubes. The laminæ are pierced by small openings; each system is made up of a subdivided open space with one large central opening and many minute ones.

Each system therefore presents the plan of a simple rhagon sponge, with its osculum and numerous ostia. Their combination to form a stromatoporoid is identical with the union of many sponge units to form one of the Demospongiæ.

Many freshwater sponges present this arrangement in a very simple form, though marine ones generally lack definite layers. Such freshwater sponges as *Trochospongilla leidyi*, however, grows in the typical stromatoporoid manner; and the thesis here presented is that the stromatoporoids are related to the Demospongiæ, and particularly to the freshwater genus *Trochospongilla*.

8. *The Nature and Relationships of the Genus Aulopora.*

By MILDRED ADAMS FENTON, University of Cincinnati, Cincinnati, Ohio

(Author's Abstract).

The name *Aulopora* has been applied to a group of supposed tabulate corals that are attached to foreign objects, and that reproduce by basal gemmation. The essential characters of the genus, however, are found also in *Stomatopora* and *Hederella*, two genera currently placed in the family *Diastoporidae*, of the cyclostomate bryozoans. There is some evidence, on the other hand, that the tubes of *Aulopora* were chitinous rather than calcareous; and it is significant that the bryozoan *Plumatella*, of the order *Phylactolæmata*, shows closely analogous structure. For the present, however, the hypothesis is advanced that *Aulopora* is a bryozoan belonging to the family *Diastoporidæ*, rather than a coral. Supposed large species of *Aulopora* actually show, in thin section, the characters of the coralline genus *Ceratopora*, and so do not affect this conclusion.

9. A Re-Study of the Hamburg, Indiana, Section.

By W. H. SHIDELER, Miami University, Oxford, Ohio.

(Author's Abstract).

The Richmond section at Hamburg, Indiana, affords the only known instance of a connection between the Cincinnati embayment and that of the upper Mississippi Valley, thus affording a means of correlating the two series of deposits.

At the Ann Arbor meeting of the Paleontological Society, on the basis of this section the lower Elkhorn of the standard Cincinnati section was correlated with the Fernvale, and the upper Elkhorn with the Maquoketa.

A restudy of the Hamburg section, and of the Fernvale and Maquoketa, strengthens the correlation of the Elkhorn as a whole with the Brainard or upper division of the Maquoketa, as developed in Iowa, Wisconsin and Illinois. The lower divisions of the Maquoketa have no known equivalents in the Cincinnati section. The problem has been made difficult by the fact that the Brainard carries a recurrent Fernvale fauna. The exact position of the Fernvale was not determined, except that it rests upon the Arnheim in Tennessee, but according to Ulrich, near Nashville, it is overlapped by Waynesville.

9a. Recurrent Faunas in the Cincinnatian

By W. H. SHIDELER, Miami University, Oxford, Ohio

(Author's Abstract)

From the Black River through the Richmond are many samples of recurrent faunas. Most of these are composed of small aggregates of species, and are not widely distributed, often being well developed only toward the outer end of a particular embayment, toward the place of origin.

In a broad sense, the Richmond as a whole is recurrent Black River-Trenton. Special faunules of the Richmond may be directly compared with special faunules in the Black River.

The Fairmount fauna of Kentucky and Tennessee carries a very large recurrent Cynthiana (Greendale)-Catheys fauna. The Fulton fauna is recurrent near the top of the Southgate, the Corryville fauna in the lower Arnheim, the Arnheim in the upper Waynesville (Blanchester), and the Fernvale in the Brainard.

10. Resumé of The Geology of Lucas County, Ohio.

By J. ERNEST CARMAN, Ohio State University, Columbus, Ohio.

(Author's Abstract).

Lucas County, located at the west end of Lake Erie, is entirely within the glacial lake plain and the surface is, in general, level. Features marking the shore lines of five of the glacial lake stages were recognized and their courses traced. These are in descending order, the Arkona, Warren, Wayne, Grassmere and Lundy. The Arkona and the Warren stages are marked by faint beach ridges; the Wayne, Grassmere and Lundy by sand hill belts, in part overlapping.

The geologic column of the county includes thirteen rock divisions ranging from the Niagara dolomite of Middle Silurian to the Ohio shale of upper Devonian and has a thickness of 700 to 800 feet.

Lucas County is on the west flank of the Cincinnati anticline and the rocks have in general a very gentle dip to the west. West of the center of the county there is a narrow north-south belt about one mile wide along which the westward dip is 6 to 8 degrees, a distinct monocline. Southward this monocline spreads out with a gentle dip but its exact course is continued southward by a fault with the upthrow on the east and with a displacement of 100 to 200 feet. This fault has been traced southward across Wood and Hancock counties.

11. The Devonian Section on Pinal Creek, Arizona.

By CLINTON R. STAUFFER, University of Minnesota, Minneapolis, Minn.

(Author's Abstract).

Pinal Creek drains the area about Globe, Arizona. The Devonian section cut by it, at the limestone hill northwest of town, includes about one hundred feet of fossiliferous gray limestones and shales. These belong to the Martin limestone as described by F. L. Ransome. The section is unusually interesting in that it carries a rather large brachiopod fauna in addition to many of the corals so abundant in the same limestone at Bisbee. As has been pointed out by H. S. Williams and others, this is the same fauna as that occurring in the Lime Creek shales of Iowa. It is widely distributed over several of the extreme southwestern states where it represents a part of the Eurasian Devonian province. Although some of its species reached the eastern part of the North American continent by late Devonian time, it is to be remembered that the fauna as a whole did not get farther in that direction than Iowa and that some of its most characteristic species are wholly lacking in the New York upper Devonian. The probability is, therefore, that the migratory route to the East, for such species as reached northern Michigan and New York, was not by way of Iowa but by some more indirect or roundabout way such as the Mackenzie valley where these same southwestern species appear to be absent.

12. Pre-Pennsylvanian Deformation in Western Kentucky.

By WILLARD ROUSE JILLSON, State Geologist of Kentucky, Frankfort, Ky.

(Author's Abstract).

The importance of giving consideration to the several major unconformities in the Paleozoic stratigraphical section when engaged in subsurface studies in Kentucky has long been recognized. Less attention than it deserves, however, has been paid by geologists to sub-surface unrevealed deformation, largely without doubt because it can usually only be indicated as a possibility even where the most painstaking efforts are expended in its investigation. That pre-Pottsville folding and faulting has occurred in Kentucky within the coal field area is now established by discoveries, the first of their kind in this state, made by the writer February 4, 1928.

In western Hart County, Kentucky, on the Nolin River within a mile of the Edmonson-Grayson County corner, there occurs at the mouth of Rock Creek near Sims Ford unmistakable pre-Pennsylvanian deformation.

On the northeast side of the panhandle of the meander of Nolin River at Sims Ford, in a low bluff Chester sandstones (Hardinsburg?) are set at angles ranging from 45 degrees to 60 degrees with strike south 10 degrees east. Within 8 or 10 feet horizontally bedded Chester limestones (Golconda) occur undisturbed. Superimposed is a strong and massive bed of the Pottsville conglomerate.

The discordant contact here of these three separated stratigraphic divisions of the Carboniferous rocks, if it be not due to a pre-Pottsville sink hole, adequate evidence for which is lacking, indicates the probability of the following sequence of geologic events: (1) Deposition of locally conformable Chester sediments; (2) Uplift, folding initialed from the south or southeast, rapid replacement of compression forces by tension, fracture and normal down-faulting on the south; (3) Subareal erosion with the development of pronounced local relief; (4) Depression and rapid deposition of the quartz sand gravels of the early Pottsville; (5) Subsequent uplift with the resultant erosion and exposure now in evidence.

13. Some Features of the Monongahela Series.

By WILBER E. STOUT, Ohio State University, Columbus, Ohio.

(Author's Abstract).

The Monongahela Series in eastern Ohio contains seven coal beds and five freshwater limestones, and extends from northern Jefferson to southern Gallia County, a distance of approximately 150 miles. Throughout the entire Ohio field both the coals and the limestones show remarkable continuity, seldom being absent and then only for short distances. The evidence thus indicates that the conditions favorable for depositories at these periods prevailed throughout the entire field, but were somewhat variable in intensity and duration, thus giving rise to differences in thickness, composition and structure of the members. Deposition during Monongahela time was regional and not local.

14. Origin of the Brines of Eastern Ohio.

By RICHARD C. LORD, Kenyon College, Gambier, Ohio.

(Author's Abstract).

The rock salt beds extending from central New York to Eastern and South Central Ohio are found in the Salina formation of Silurian age. The Stassfurt deposits in Germany and the Kansas and Texas rock salt beds are found in the Permian period, decidedly more recent in geologic time.

In the sandstones and porous limestones above the Salina, in the basin west of the Appalachian mountains, are found brines, unique in the chemical composition, and in which the ratio of calcium, magnesium and bromin is an approximate constant. The content of calcium chlorid is somewhat more than twice the magnesium chlorid content. These

brines are probably the result of bittern, which did not crystallize when the salt beds of the Salina were formed in a closed basin, and which has become diluted to brines of varying strengths, by water which has infiltrated laterally in various formations, in a manner similar to water from artesian wells. Deductions as to the ratio of the various salts in oceanic water in Silurian time as contrasted with the present ocean water, may be drawn.

15. *Features Common to the Appalachian Zinc Deposits.*

By LAWRENCE FREEMAN, University of Cincinnati, Cincinnati, Ohio.

(Author's Abstract).

Some characteristics brought out in state reports concerning the zinc deposits of Pennsylvania, Virginia, and Tennessee seem to be constant over the region at large. The zinc ores are practically limited to the dolomitic limestones of Cambro-Ordovician age, with dolomite as a gangue mineral. The sphalerite is concentrated in breccia zones in the dolomites and cherts where replacement of these by the zinc sulphide has been an important factor in ore deposition.

The commonness of light-colored sphalerite in this region is brought out. This variety, containing little iron, possibly represents secondary sphalerite. Iron going into solution with sphalerite in limestones does not travel far but is almost immediately precipitated as limonite due to the neutralizing environment. The iron oxide found lining individual cells in the oxidized zone may in part represent iron present in the original sphalerite. The zinc sulphide in solution would be carried to greater depths before being precipitated as sphalerite. If light-colored sphalerite results from secondary concentration, then the commonness of this variety of sphalerite within the region described might be helpful in establishing the secondary origin of much of the ore.

16. *Some Features of the Borden (Knobstone) Rocks of Southern Indiana.*

By PARIS B. STOCKDALE, Ohio State University, Columbus, Ohio.

(Author's Abstract).

The stratigraphy of the Borden (Knobstone) division of Mississippian strata in southern Indiana has been studied by the writer during the past two field seasons. Previous works on these rocks have been incomplete and disconnected. Because of the undesirability of a descriptive word, the term "Knobstone" was abandoned, and "Borden," from the village of Borden, was introduced by E. R. Cumings in 1922.

The Borden rocks, often correlated with the Waverly of Ohio, lie upon the Rockford (Kinderhook) limestone. They are overlain by the Harrodsburg (Warsaw) limestone. Thus, they represent a distinct stratigraphic unit of predominantly clastic material, sharply delimited. South of the glacial boundary, the rock group thins from north to south, and east to west, maximum thickness being nearly 800 feet. The Borden displays marked variability both vertically and laterally, and lacks, with one exception, well-defined, persistent horizons to designate formation subdivisions.

In the vicinity of Borden, the basal 150 feet is a pure shale. Upwards, this grades into sandy shale, the transition being very gradual. Finally, it passes into a massive sandstone (400 feet above the base), which has a thickness of 100 feet, and is characterized by large brachiopods, especially *Syringothyris textus* and *Orthotetes keokuk*, and abundant bryozoa. Above the sandstone is a lenticular limestone, up to five feet thick, named the Steven's Creek limestone by C. A. Malott. Overlying this are 40 feet of alternating sandstone and sandy shale layers, non-fossiliferous. Variations from the type section, and many special features furnish interesting complexities.

17. Cenozoic History of the Montana Front Ranges.

By ARTHUR BEVAN, University of Illinois, Urbana, Illinois.

(Author's Abstract).

The Rocky Mountains do not have a single front range in Montana, but the frontal zone consists mainly of five distinct ranges which are aligned in an almost unbroken northwesterly belt. Two or three ranges not directly aligned with the others are closely related to them. Each range appears to be a separate structural unit, whose Cenozoic history has differed sufficiently to impress individual characteristics on it. Each member of the front range group, however, was probably affected considerably by certain major cycles of events.

Until the history of each range has been deciphered in some detail, it is hazardous to interpret one range in terms of another or to generalize for the entire region. The known data permit, however, this provisional outline of the major Cenozoic events as a basis for future studies:

1. Late Cretaceous and early Tertiary orogeny developed overturned folds and overthrusts which form the main structural lineaments.

2. Early (?) Tertiary vulcanism, both intrusive and extrusive, added smaller ranges to the main group and partially altered some of the folded and faulted ranges.

3. Pre-Middle Miocene erosion reduced at least a few ranges to surfaces of low relief, and, perhaps, to an extensive peneplain.

4. Local vulcanism occurred during the Miocene.

5. Middle (?) Miocene vertical uplift with some warping; folding and faulting relatively unimportant.

6. Pre-Quaternary erosion to mature or old-age surfaces.

7. Early Pleistocene vertical uplift with gentle warping.

8. Pleistocene glaciation in at least three stages, with some intervening, and perhaps post-glacial, vertical uplift.

18. A Recently Abandoned Entrenched Meander.

By WILLARD ROUSE JILLSON, State Geologist of Kentucky, Frankfort, Ky.

(Author's Abstract).

Abandoned stream meanders in old low lands are commonplace, abandoned entrenched meanders evidently of Pleistocene or greater age are not uncommon in certain limestone districts such as the Bluegrass of central northern Kentucky, but recently abandoned entrenched meanders are sufficiently unusual to hold the layman's attention and

give the geologist pause. In a remote part of Western Kentucky about twelve miles northeast of the Mammoth Cave, on the lower waters of Dog Creek, a northwest flowing tributary of the Nolin River, such a unique physiographic feature is well developed and has not previously been described. This meander was observed and photographed by the writer February 5th, 1928.

As is the case in many abandoned meanders, this feature was produced by lateral cutting on the outside of two closely adjacent "moccasin" bends in the course of Dog Creek. Field evidence indicates that cutting in the toe of each of these abutting but distinct meanders advanced until not more than 15 or 20 feet of the dividing ridge of thin bedded Glen Dean limestone remained. About this time solution along bedding and joint planes must have been greatly aided by fine abrasive materials in the form of sharp silica sand with which this stream is abundantly supplied. Perhaps a natural limestone bridge existed for a short time.

Collapse of this rock span followed by a rather rapid removal of the fallen calcareous blocks came in sequence, but this stage has been so recently completed that a uniform gradient has not yet been established across the breach which itself is hardly fifty feet across. In effecting the "cut off" Dog Creek shortened its course upwards of one and one-half miles, superinduced rapid downward cutting of several feet in its limestone bed just above the "breach" with the resulting development of about 400 feet of low cascades or rapids. These were utilized by early residents for water power purposes.

The opening of the "breach" is still actively in progress but has not progressed far enough yet to allow even a foot path through it at water level. From whatever angle it may be viewed this cut-off is recent, very recent.

While one is impressed with this fact, natives indicate that no change has occurred here since the period of settlement, upwards of 100 years or more ago. Stream erosion is admittedly slow, rock falls under such conditions as here depicted could not be other than so gradual as to fail to startle the untrained native observer. Measured, however, beside personally observed Greek, Roman, and early British limestone walls, all now in various stages of disintegration, this "breach," subjected to the occasional though certain torrential flood waters of Dog Creek, may reasonably be assured to have occurred originally between 500 and 1000 years ago.

19. *The Filled Valleys of Western Kentucky.*

By CHARLES V. THEIS, University of Cincinnati, Cincinnati, Ohio.

(Author's Abstract).

This paper aims to trace the development of the broad filled valleys of the western Kentucky coal field.

It is shown that the rock bed of the Ohio and tributary streams in this section probably represents two stages of cutting; a first, in which a broad platform was developed at an elevation of about 300 feet in this section, and a second, in which a trench was sunk about 100 feet deeper. The date of this cutting was probably early Pleistocene.

The main filling of these valleys, as now preserved, was performed in Wisconsin time, as proven by tracing the terrace level up stream.

The assumption frequently made that these broad filled valleys indicate differential depression of this region is shown to be erroneous because the river is now cutting at the elevation at which it cut when the broad valleys were excavated. On the other hand it is shown that there has probably been depression since the time of cutting of the trench. This depression, however, is probably not limited to this region.

20. Observations on Some Cincinnati Landslides.

By J. K. ROGERS, University of Cincinnati, Cincinnati, Ohio.

(Author's Abstract).

The object of the paper is to call attention to features observed in connection with several landslides, not to present generalized conclusions.

A slide occurred on the slope below Bethesda Hospital in thick glacial till and terrace material; probably the movement here did not extend down to the bedrock surface.

At Sedansville the sliding has been more extensive and much more destructive, affecting seriously the switching facilities of the Big Four Railroad over a length of an eighth of a mile, and destroying a number of residences. The original angle of slope was probably twelve degrees. The pattern of cracks developed, as shown on a sketch map of the area, is characteristic of the slides so far observed.

Four or five smaller slides are described, notably one below McMicken Avenue; these are of the same general type, but differ in some important respects.

Several generalizations seem justified from the cases considered: The sliding here has been confined to unconsolidated material, chiefly glacial till and terrace deposits. These materials are plastic and flow readily when wet. The more extensive of the slides here considered have taken place on slopes of about twelve degrees. In each case, cracking has been prominent, concentric cracks appearing at the upper limit of the slide, enechelon cracks at the lateral margins. Undercutting at the base of the slope and saturation below the surface of the clay or till are important as contributing factors.

21. The Depth of Leaching of the Early Wisconsin Drift in Ohio.

By G. W. CONREY and T. C. GREEN, Ohio Agricultural Experiment Station, Wooster, Ohio.

(Authors' Abstract).

From the standpoint of age the Early Wisconsin drift is intermediate between the Late Wisconsin and Illinoian drift. The Illinoian drift in southwestern Ohio has been leached of carbonates to a depth of 8 to 10 feet, the Late Wisconsin to 2 or 3 feet. Over much of Butler County the depth of leaching of the Early Wisconsin drift is little, if any greater than the Late Wisconsin. However, in favorable sites, such as broad undulating to gently rolling areas the depth to lime may be as much as 48 to 56 inches. Apparently the rolling surface of much of Butler County, with sheet wash on some relatively smooth areas has been a factor in producing a shallower leached zone over much of the county.

In the Early Wisconsin drift there is a well defined transition zone, free from carbonates, between the heavy upper subsoil, and the calcareous unleached till, which is either very thin or entirely lacking in the Late Wisconsin drift.

It is very evident that care must be used in selecting sites for studying the depth of leaching or very erroneous conclusions may be drawn.

22. Eolian Versus Subaqueous Cross-Bedding.

By WALTER H. BUCHER, University of Cincinnati, Cincinnati, Ohio.
(Author's Abstract).

The lines that constitute the pattern of "cross-bedding" are the outcrops of surfaces of two kinds that represent opposite processes. The laminæ of ordinary cross-bedding represent surfaces of *deposition*, while the surface that normally teminates them above, represents a surface of *removal*. Attempts to distinguish between subaqueous and eolian cross-bedding (by Grabau and others) have been directed toward the details of the contact of laminæ of deposition with adjoining surfaces of removal. Twice the writer has made careful observations on the character of cross-bedding in the Indiana dunes at the south end of Lake Michigan, with the following result. In these dunes laminæ of deposit with adjacent surfaces of removal form layers up to a foot or two in thickness quite comparable to fluviatile cross-bedding. For tens of feet the surfaces of removal form a series of roughly parallel lines in the outcrop simulating the subparallel bedding of fluviatile sediments. In the Indiana dunes there exist, however, surfaces of a higher order, cutting obliquely across the cross-bedded layers below them and having above them another thickness of cross-bedded sands roughly parallel to the new inclined base. To the writer it seems that the presence of these surfaces of removal of a second or higher order is the only true criterion of eolian cross-bedding.

This point is illustrated by pictures taken by the author and by other observers.

22a. The Erosional History of the Blue Ridge.

By FRANK J. WRIGHT, Denison University, Granville, Ohio.
(Author's Abstract).

Keith in his study of the Blue Ridge of the south, described two peneplanes in addition to the magnificent erosion surface of the Piedmont to the southeast. These have been recognized by the present writer. Keith interpreted them as representing the work of three cycles of erosion. The highest erosion level, developed over broad areas, now stands at elevations varying from 3,000 to nearly 4,000 feet, and probably corresponds to the Upland or Cretaceous (?) peneplane of the Newer Appalachians. The second level, represented by the Asheville surface, is preserved in a number of valleys from 2,200 feet, around Asheville, to over 3,000 feet in the higher basins. It is suggested by the writer that this series of local high-lying peneplanes in the older Appalachians was developed contemporaneously with the Piedmont peneplane on the southeast and the Appalachian Valley (Tertiary ?) peneplane on the northwest.

D. SECTION OF MEDICAL SCIENCE.

EMERY R. HAYHURST, Ohio State University, *Vice-President.*

23. Cyclic Variations in the Basal Metabolic Rates of Normal Women.

BY FRANCES R. WARDWELL and FRED A. HITCHCOCK, Ohio State University, Columbus, Ohio.

(Authors' Abstract).

The work reported in this paper includes 475 Basal Metabolic Rate determinations made with the Benedict-Roth Graphic type of apparatus. Of these 125 were run during the menstrual flow and 350 during the intermenstrual periods. They were run consecutively on 21 different women, students at Ohio State University during different periods of the year.

It was concluded that information secured gave added data to support the view that:

1. The metabolic rates of normal women are subject to a cyclic variation;

2. That the lowest point in this cycle occurred during the normal menstrual flow;

3. That the amount of variation in each test reported, is greater than twice the statistical probable error.

24. The Clinical Importance of Aberrant Tissues.

By KELLEY HALE, M. D., Wilmington, Ohio.

(Author's Abstract).

Aberrant tissues are not to be confused with doubling or duplication of organs and are defined as a piece of an organ which has strayed away from and having no connection with the parent organ but possessing histologically all or nearly all of the normal elements. Serious and sometimes fatal issues result from aberrant or accessory tissues and they give trouble not only as a mechanical agent but possess malignant potentialities. Notation with references are made to the numerous situations of aberrant tissues.

The author presents the following cases of his own:

Case 1. Patient having a small movable tumor in the posterior triangle of the left side of her neck which proved on microscopic examination to be a colloid goiter developing from an accessory thyroid. Roentgenogram of this patient's chest revealed a large smooth mediastinal tumor which has proved to be an accessory mediastinal thyroid; malignancy having been ruled out by treatment and time.

Case 2. Accessory pancreas causing congenital pyloric stenosis in a six weeks' old infant. Death followed Rammstedt's operation. It is thought that the activity of the cells of the aberrant pancreas irritated the musculature of the pylorus to such an extent as to cause pathologic changes. Thereby another solution is added to the etiology of this disease. This case was fully reported in Annals of Surgery, June, 1926.

Case 3. A patient manifesting symptoms of acute appendicitis at laparotomy was found to have a kidney-colored, encapsulated tumor

which on section revealed typical and distorted tubules with an occasional renal cell. No glomeruli were present. This tumor was classified as either aberrant renal or Wolffian body tissue.

Only a thorough study of embryology will reveal the mystery of how aberrant tissues come to be. Being interested in the yet undiscovered controlling mechanism of ontogeny, the author has found in the eggs of the physa and other fresh water gasteropods, fine equatorial lines located in the inner cell membrane resembling phonographic lines. Research from year to year has led to the discovery of a very complex set of meridinal lines that radiated from a very definite point located not far from the lesser end of the egg within the inner cell membrane and extending a variable distance beyond the equator. At first they are refractile lines, later breaking up into strands of beads and have a bilateral arrangement. Theoretically these lines can be fitted into the role of that undiscovered controlling mechanism of ontogeny.

Aberrant nodules, duplication of organs and the multitude of anomalies, atavism, evolution and mutations will not be understood until this control is discovered.

25. A Statistical Study of the Infectious Diseases in the City of Columbus, Ohio, for the Past Twenty-five Years.

By DELBERT A. MINDER, Columbus, Ohio.

(Author's Abstract).

Using as an index Typhoid Fever, Measles, Whooping Cough, Diphtheria, Influenza, Lethargic Encephalitis, Meningitis, Scarlet Fever, Broncho and Lobar Pneumonia, a preliminary survey regarding the mortality, the relative increase or decrease of all the acute infectious diseases was made.

The data used was secured from the vital statistics of the City Board of Health at Columbus, Ohio. The yearly increase in population was obtained from the United States Bureau of Census. Charts were made showing the actual mortality rate per 100,000 population for every month during the years of 1907 to 1925 inclusive. Likewise a similar chart showing the general mortality for all the acute infectious diseases was made and analyzed.

Considering those diseases which were used as an index, an analysis of the charts used showed: First: Typhoid Fever, Diphtheria, Scarlet Fever, Measles, Meningitis, are rapidly declining as a cause of death. This decline in death from the acute infectious diseases is an important factor in prolonging life. Second: Those diseases which seem to affect the respiratory system are on the increase. These are essentially Influenza, Broncho and Lobar Pneumonia. Third: That the first death from Lethargic Encephalitis was not reported until 1920 and that this disease is on the increase.

The chart showing the general mortality revealed that: First: Excluding a few flare-ups which have been considered to be epidemics, it can be said that death from the acute infectious diseases is on the decline. Second: This decline is neither marked nor rapid, but on the contrary is quite gradual. Third: Since the actual mortality is an index

to the frequency of occurrence of these diseases the statement can be safely made that they are occurring almost as often as they used to occur. Fourth: This chart coroborates the previous statement that the chief contributors to the number of deaths are from those diseases which affect the respiratory tract. Fifth: Most of our epidemics have and still are occurring during the winter months. Sixth: The majority of deaths happen in the first one-third of the year. The least number of deaths occur in the summer time.

26. Review of Occupational Disease Report.

By BYRON E. NEISWANDER, M. D., Chief, Division of Industrial Hygiene, Columbus, Ohio.

(Author's Abstract).

The Division of Industrial Hygiene has recently completed a statistical study of the occupational diseases reported to the State Department of Health in the last two and one-half years ending December 31, 1927.

During that time a total of 2,930 cases were reported by the physicians of the state, of which 2,738 were included in the list compensated by the Industrial Commission similar to accidents and 192 were occupational diseases not compensable. The above figures show that the great majority of diseases reported are those which are classed as compensable though comparison with the figures for the previous five years (1921–1925), show that non-compensable case reports are increasing very rapidly. The yearly average increase of compensable diseases is 71% and of non-compensable 997%.

Evidently the systems of spread of information promoted by the State Department of Health and the Department of Industrial Relations are bringing results. Some interesting points shown are:

1. No cases of anthrax, glanders, phosphorus, or wood alcohol, all in the compensable list, have been reported in the last two and one-half years.

2. Lead poisoning, which is compensable, is a most important source of occupational diseases—450 cases.

3. Dermatoses make up the great majority of those cases which are compensable—2,210 cases, of which 608 occurred in the rubber industry.

4. Oils and cutting compounds used with metal products are excellent media for the spread of infections of the skin—395 cases.

5. Three groups show a decline in the number of cases reported, namely, lead poisoning in automobile manufacturing, benzol poisoning, and dermatoses in rubber plants.

6. The Division of Industrial Hygiene will publish its full findings in the near future.

27. Mitochondria of the Kidney in Acute Experimental Bichloride Nephritis.

By SAMUEL GOLDSTEIN and AARON S. CANOWITZ, Columbus, Ohio.

(Authors' Abstract).

An attempt has been made to determine the variations that mitochondria undergo in bichloride nephritis and to correlate these findings

with the degree of functional impairment of the cells involved. The mitochondria were best studied with the anilin fuchsin-methyl green stain (Cowdry's modification), but iron hematoxylin and Janus green B were also used. White rats were used and blood urea determinations were made on all animals just prior to death. After carefully eliminating all normal variations the following conclusions were reached: The mitochondria of the proximal convoluted tubule, being predominately rod like, underwent a gradual transformation into the granular form and, in more advanced stages of the disease, the granules enlarged and coalesced into droplets and larger masses with lipoidal staining qualities. These changes occur before the disease is evident by ordinary staining, these variations constituting, therefore, anatomic changes indicating pathologic processes which would ordinarily be overlooked. In view of the fact that a high degree of urea retention is present with only very slight mitochondrial alterations, we are led to assume that secretion is not dependent upon mitochondria nor are mitochondria altered very greatly by inhibition of secretion.

28. Health Habits of University Women Students.

By NORMA SELBERT, R. N., B. S., M. A., College of Medicine, Ohio State University, Columbus, Ohio.

(Author's Abstract).

The object of this paper: to present problems connected with the health habits of women who were students in the Ohio State University during 1927–1928. The study included inquiry using a questionnaire, personal conferences, and visits to students' homes.

The questions are based on "Rules of the Health Game," advocated by The American Child Health Association and the Bureau of Education in the U. S. Dept. of the Interior; the "Health Chores" advocated by the National Tuberculosis Association; and also the principles adopted by the Joint Committee of the National Education Association and the American Medical Association. "The 'Health Behavior Scales'" recently published by Dr. Thomas D. Wood and Dr. Marion Lerrigo include standards which these questions suggest. These are answers to questions asked while making study:

	Affirmative	Negative
1. Do you take a bath more than once a week?	280	4
2. Do you brush your teeth thoroughly at least once a day?	281	3 did not reply
3. Do you sleep 8 hours out of every 24?	75	209
4. Do you sleep with one or more windows open?	280	4
5. Do you drink a pint of milk each day?	20	264
6. Do you drink tea oftener than once a day?	10	274
7. Do you drink coffee oftener than once a day?	194	90
8. Do you eat fruit or vegetable each meal?	80	204
9. Do you drink at least four glasses of water each day?	75	209
10. Do you play out of doors a part of every day?	90	194
11. Do you have a bowel movement every morning?	124	160
12. Do you work four or more hours each day, except Sundays?	284	

The daily living of the student may be regarded as an index to what he applies or that which he or she has learned in hygiene. Answers to questionnaires, such as this, usually indicate whether or not parents and teachers have been successful in training young people to habits which they should have formed before they reached college.

Health is largely personal responsibility, but the teaching of hygiene will never be more than superficially effective until teachers are concerned with conditions under which students must sleep and eat and work. It is not enough to tell a student that he must sleep in a well ventilated room. He should know why it is essential to have fresh air at all times and how he can provide healthful ventilation for himself. He should be taught how to analyze, and how to transform his environment so as to promote health.

Many who are teaching hygiene lack the medical background necessary for teaching. Many who are teaching lack what is necessary to teach hygiene effectively, even though they possess sound training in medical sciences. Knowledge of certain subject matter is not sufficient for successful teaching. The technique of superior teaching includes much which is not taught in medical schools. "The chief criticism of hygiene, as taught by the usual instructor, is that it is academic." Most teachers tend to develop the subject far beyond its usefulness, and they are frequently formalists. Instruction in hygiene should be practical and should be connected with conditions under which the student must live. The aim should be to develop an individual who can live at his best wherever he may find himself.

29. Experimental Tar Cancer.

By HARRY L. REINHART and ROBERT L. SOLT, Department of Pathology, Ohio State University, Columbus, Ohio.

(Authors' Abstract).

A review of the history of Experimental Tar Cancer reveals that it was the logical result of observations on the occurrence of industrial tar cancer. The experimental production of Tar Cancer was delayed for many years as a result of three factors, which are now well known, viz., (1) variations in coal tar, (2) variations in susceptibility of laboratory animals, and (3) the length of time that the irritant must be applied before the malignancy develops. With the increasing production of experimental tar cancer in many laboratories, all of these factors have been more or less modified. However, their fundamental importance is still manifest, and of these factors, the length of time necessary for a carcinogenic tar to produce a definite malignancy in a susceptible animal, is the most important, and adds weight to the theory of chronic irritation.

In our own experiments, using samples of tar from various sections of the country, obtained through the courtesy of the Department of Mining Engineering of the Ohio State University, we have produced tar cancer in white mice and rabbits. These experiments are of a preliminary nature, and have been conducted that we might observe the development of tar cancer, determine which of our samples of tar are potentially carcinogenic, and improve our technique for a continuation of the work.

30.   Treatment of Typhoid Fever with Detoxicated Vaccine.

By W. B. WHERRY, Cincinnati General Hospital, Cincinnati, Ohio.

(Author's Abstract).

The vaccine is prepared by treating the antigen with formaldehyde, the method used by Ramon of the Pasteur Institute of Paris in the production of anatoxins—detoxicated toxins which retain their antigenic properties. This method does not completely detoxicate the typhoid bacillus but experience has shown that about 100,000,000 (0.1cc) treated bacilli may be injected subcutaneously into a typhoid patient, daily, without any harm. Such injections are followed by a local area of congestion which subsides in 24 to 36 hours.

The results obtained in treating 28 cases of typhoid diagnosed bacteriologically early in the course of the disease as compared with 68 controls will appear shortly in the Journal of Infectious Diseases. The findings are briefly: (1) the temperature tends to fall to normal after the seventh or eighth daily dose and proceeds to normal by an irregular lysis, the course of the disease being greatly shortened when early treatment is given; (2) there appears to be a marked reduction in the mortality and the number of complications; (3) cases given early treatment have a rapid convalescence; (4) even late toxic cases seem to be benefited by the treatment.

(Physicians desiring to use the vaccine will communicate directly with Dr. John E. Monger, State Department of Health, Columbus, Ohio, or with Dr. W. B. Wherry, Cincinnati General Hospital.)

31.   Tartrate Nephritis.

By ERNEST SCOTT and SAMUEL CLIMO, Department of Pathology, Ohio State University, Columbus, Ohio.

(Authors' Abstract).

A survey of the literature covering experimental tartrate nephritis was rendered. Apparently no work has been done up to the present time, in which the albino rat has been employed as the experimental animal and consequently it seems of some value that the effects of tartrate upon the rat kidney be determined and compared with the nephritis occurring in other types of laboratory animals following the administration of tartrates.

32.   Multiple Myeloma.

By KARL D. WAY, DR. F. M. STANTON, and DR. ERNEST SCOTT, Department of Pathology, Ohio State University, Columbus, Ohio.

(Authors' Abstract).

The literature contains the report of 169 cases of well authenticated cases of multiple myeloma, the diagnosis of such cases being based upon a histological examination. The peculiarities of this type of tumor consist in the fact that they originate in the bone marrow and may involve many of the bones of the body simultaneously. The tumor cell is a derivative of bone marrow cell, in some instances arising definitely

from the granular series, in other cases apparently from the lymphoid tissues. The usual microscopic appearance is that of a rather large plasma cell. To the number found in literature, the Laboratory of Pathology, the Ohio State University, is adding three (3) additional cases.

33. The Histogenesis of Malignant Mesenchymal Tumors of the Kidney.

By BERNARD E. INGMIRE, Department of Pathology, Ohio State University, Columbus, Ohio.

(Author's Abstract).

A group of tumors of the kidney have been observed in which there are a number of cell types: mesenchyme, adenomatous acini, glomeruli, cartilage, bone, smooth muscle, fat, connective tissue. These tumors have been called by a variety of names: adenomyosarcoma, embryoma, embryonal adenosarcoma, embryonic sarcoma, mesothelioma, embryonal adenocarcinoma, myxosarcoma, Wilm's tumor, teratoma, and sarcoma. After a review of the literature, a study of seven specimens in the Museum of Pathology, at The Ohio State University, and a careful survey of the embryology of the kidney, it is our opinion that these tumors are all derived from one source—the mesenchyme of the nephrogenic ridge and that the variation which is observed is the result of individual variation from case to case, and also in a great many cases from a failure to examine a sufficiently large amount of tissue of any one tumor.

(NOTE.—Abstracts 46 and 47 also belong to this Section.)

E. SECTION OF PSYCHOLOGY.

A. SOPHIE ROGERS, Ohio State University, *Vice-President.*

34. Disabilities in College Students in Certain "Tool Subjects" and the Relation of Such Disabilities to College Standing.

By HENRY J. ARNOLD, Wittenberg College, Springfield, Ohio.

(Author's Abstract).

That deficiencies in background preparation constitute a serious handicap to a student's academic success in college, has become almost axiomatic with college administrators and instructors. However, in general, efforts to determine the specific nature and extent of such deficiencies as the student may have when he enters college, have been almost negligible.

Recent studies carried on by the Department of Educational Psychology of Ohio State University have revealed striking deficiencies in the so-called "tool subjects" of students entering the university, and point out the extent to which such disabilities may be corrected by the student himself provided the remedial work is carefully planned and

executed. It is shown that college standing of students can be materially raised by adequate methods of rehabilitation.

In an attempt to secure further evidence bearing on this problem, a group of diagnostic tests in the various "tool subjects" was given to several classes of under-classmen (mostly Freshmen) at a certain Ohio College. In this report, the results of two of the tests, Arithmetic (Monroe's Diagnostic) and Algebra, (Hotz' Scales) are given as being typical of the findings for the entire series.

In the Arithmetic, 24% scored below the eighth grade norm in all the 21 tests, while 41% average below the same level in four tests in division. Zero scores average over twice as common in division as in multiplication. More than 50% of the zero scores were made in fractions. 31% failed at least one test in fractions and three made zero on four out of five of the fraction tests. Eight students out of the 83 scored zero on four or more tests. It is shown that such deficiency in Arithmetic constitutes a noticeable handicap in Chemistry which requires proficiency in rather complicated Arithmetical processes. Another group of 40 students (Freshmen) showed a gain of 41% improvement on the Monroe Diagnostic Tests in Arithmetic following a six-weeks period of remedial instruction involving the specific deficiencies as determined by the original test. These 40 students had received "below passing" scores in the first trial.

The deficiencies in elementary Algebra, as revealed by an analysis of the errors, were equally striking. The percents of the fifty-three students who scored below the standard norms for first year high school pupils in each of the scales are as follows: Addition and subtraction, 75%; multiplication and division, 76%; equation and formula, 56%; problems. 56%; graphs, 58%, or an average for all tests of 64%. The greatest deficiency was found in ability to handle operations with fractions, the difficulty centering around inverting of the divisor, least common denominator and factoring preparatory to cancellation. Some of the other difficulties which lowered total scores were: removing parenthesis, forming a simple equation, transposition, removing radicals and simplification. The errors were all of such a nature that, with proper remedial practice, the student could soon remove the deficiency. The close relation between elementary algebra and physics, and the significance of algebra in trigonometry and other branches of college mathematics, emphasizes the necessity of assisting the student to master the fundamental operations in the elementary course.

It is maintained that colleges should assume the responsibility of aiding students who have deficiencies in tool subjects by (1) determining, by means of diagnostic tests and other diagnostic methods, the specific nature and extent of such deficiencies, and (2) by providing carefully developed methods for remedial instruction. It is claimed that such procedure will, if properly carried out, do remarkable things in the way of rehabilitating many college students whose progress through college might otherwise be greatly impeded. It is also suggested that a college "educational diagnostician" could do much to prevent failures and raise the general level of college work.

35.   Some Specifications for an Elementary Text in Psychology.

By WILLIAM R. WILSON, Ohio State University, Columbus, Ohio.

(Author's Abstract).

It is desirable that teachers of elementary psychology work out definitely their educational aims. Elementary text books in psychology should be evaluated using these aims as criteria. Commonly the aim of the teacher of psychology is to give information, which in practice means bringing about the formation of precarious verbal habits. Probably the most important justification for elementary psychology is not its value as information but the training value that it may be made to possess. It cannot be safely assumed that information and training go hand in hand. With training in scientific method in the field of psychology taken as a criterion certain specifications for a utopian text are laid down. This model text will not be "eclectic" but will present a highly consistent system throughout. It will make no effort to please all readers by being all things to all men. If it errs by being dogmatic this is a venal sin to be preferred to the muddled eclecticism of the conventional text. The writer will avoid dogmatis, however, by realizing that the "scientific fact" is a fiction and by pointing out clearly the part that system making plays in psychology. The general problems of the science will be rather fully presented. This will require considerable space, but that will be a gain as it will necessitate the elimination of a vast amount of traditional material included in most texts for no valid educational reason. The conventional handling of the nervous system will be considered in detail as an example of this useless verbiage. Finally, the text will be representative of the state of psychology in the year in which it is written.

36.   Student Self-Rating in Quality of Work.

By JAMES P. PORTER, Ohio University, Athens, Ohio.

(Author's Abstract).

How accurate an estimate can the student make of his grade some ten days before the close of the semester? Such an estimate may be of value in itself. It may also be an indicator of a tendency toward over- or -under-estimation or of accurate judgment in other respects.

This study yet in its preliminary stages was undertaken to learn if possible what are the influences on estimated grades of the kind and number of tests or examinations, the kind of instruction used—whether merely lectures or both lecture and laboratory—and the personality of the instructor.

An able young woman practiced in teaching and the giving of objective tests was furnished with a graphic rating scale with carefully written instructions and phrases beneath the line to be checked as follows: "Excellent," "Above Average," "Average," "Poor," and "Below Passing."

Our scoring stencil differed most from the theoretical grade distribution and the actual one at Ohio by somewhat smaller percentages for B and C and larger for E and F. Inasmuch as the same stencil was

applied to all students the amounts assigned to each does not essentially matter.

Two groups of students made up of classes in English, History, Biology, Psychology, etc., 475 in one and 563 in another, have furnished estimates. In the first about 50 per cent estimate correctly their later letter grade; in the second but 44 per cent estimate correctly. In the first group somewhat less than 33 per cent over-estimate by one, two or three letter grades their actual grades while about 17 per cent under-estimate their grade by one or more. In the second group of 563 about 37 per cent over-estimate and 19 per cent under-estimate their grade.

Assuming that the grade is the equivalent of a trade-test score, we may conclude that college students do rate themselves as to quality of work with considerably more accuracy than did the 250,000 men trade-tested in the army. Stronger motivation of the latter would be significant probably in any attempted explanation of these differences.

The women exceed the men in under-estimating their grades while the men exceed the women in over-estimating. Both are approximately equal in accurate ratings.

If we determine the median centile rank of the three groups—those who over-estimate, under-estimate, and those whose estimates are correct—we find that as a rule the less able or intelligent over-estimate, the most able under-estimate; the median able are more often accurate. If these self-estimates have any bearing on what these students attempt to achieve particularly in later life, the political, industrial and social significance of our findings may be very great.

Correlations by the rank-order method for some of our groups between the centile ranks, actual grades and estimated grades, range from .695 to practically .00. In classes with frequent and objective tests and with laboratory instruction the correlations tend to be higher, both of ability with actual and with estimated grades. As a rule the actual grades agree a little better with ability than the estimated grades.

37. The Socialization of Experience.

By MARTIN L. REYMERT, Wittenberg College, Springfield, Ohio.

(Author's Abstract).

Preliminary experimentation with about 400 children of the ages 5–15, on the building up of social concepts from symbol visual stimuli, like lines of various widths, angles of varying degrees, etc.

The results suggest several definite lines of growth in socialization of this kind of simple experience, and seem to go well with the theoretical basis for the "Ganzheit-psychologie" of F. Krueger and also with H. L. Hollingworth's system of "Red-integrative Sequence in the Psycho-Physical Continuum."

38. Pseudoptics and the Insane.

By HOMER G. BISHOP, Wittenberg College, Springfield, Ohio.

(Author's Abstract).

Studies of the insane are generally made from the practical point of view of the law and of society or, by the psychiatrist, as the collapse

of mental faculties. Psychology demands a knowledge of the insane mind as it is. Such knowledge may be obtained by forcing the insane to perceive and record their perceptions. Data taken by direct perception ought to be reliable, if they are of immediate situations. If such perceptual situations furnished opportunity for false interpretations, this feature might make them of more value in testing the perceptual sanity of the insane. Pseudoptical figures meet these requirements.

Interpretations of illusions of length and direction of lines and of form and size of figures, in the Bradley pseudoptical series, were secured, some without difficulty others only by patient but not suggestive persistence, in twelve insane patients. Their interpretations agreed with those of normal individuals. They felt the contradiction between "real" and illusory properties of the figures, which are felt by normal subjects.

These results indicate that insanity need not be at the point of contact with the external world but arises in organization of initial interpretations.

39. A Preliminary Report on an Experimental Investigation of the Myer's Learning Curve Equation.

By WILLARD L. VALENTINE, Ohio Wesleyan University, Delaware, Ohio.

(Author's Abstract).

Some psychologists believe that learning is rapid at first, gradually slowing down following some law of diminishing returns, and can be represented by some such mathematical function, as an *hyperbola* (Thurstone). Others believe that learning is slow at first, progressing at an ever increasing rate through an inflection point and then at an ever decreasing rate to a limit. The *arc cot* function gives a good fit to data of this kind (Myer). These two views are not antagonistic; they are complementary (Culler). Where inflection points are not obtained the subjects have previously had equivalent practice in the problem in other connections before they begin formal practice upon the problem at hand. This previous practice should become increasingly less as the subject becomes younger. Data obtained from rats 18, 20, 22 and 24 days old indicate that the inflection point does not exist in simple maze running in the white rat.

40. Auditory Discrimination in White Rats.

By DOROTHY ROSE DISHER, Ohio Wesleyan University, Delaware, Ohio.

(Author's Abstract).

Hunter's work on auditory discrimination shows that the white rat can discriminate between noise and tone, between noise and silence, but not between tone and silence. This experiment was begun because the stimuli in Hunter's experiment were not well defined: hand-claps, buzzer, etc. Hunter verified his own conclusions after plans for this work were begun. We used a simple discrimination box instead of a T-maze, and an audion produced tone. This is not a "pure" tone, certain harmonics being introduced by the telephone receiver. The rat was punished by withholding food when an incorrect choice was made.

The following is a summary of our results:

Stimulus	No. of Animals	No. of Trials
2370 d. v. + silence.................	12	400 to 600
3072 d. v. + silence.................	10	500
1624 d. v. + 2730 d. v..............	4	600

Under these conditions the rats failed to discriminate.

When a rat is stimulated with a tone or noise Preyer's ear-muscle reflex is said to be a response (Wada). This reflex could be observed when the rat was stimulated with a loud noise or a loud tone. With the less intense tones used in this experiment the observations were inconclusive. Experiments with the more intense tones have not yet been completed. Should the ear-muscle reflex be evidence that the rat hears, and the rat does not learn the problem of adjusting gross bodily movement to the more intense tone then it will be necessary to restate the fundamental assumption regarding discrimination in animals.

F. SECTION OF PHYSICAL SCIENCES.

FREDERICK C. BLAKE, Ohio State University, *Vice-President.*

41. An Effective Method of Demonstrating Lissajous' Figures.

By RAY LEE EDWARDS, Miami University, Oxford, Ohio.

(Author's Abstract).

A low-frequency electric oscillator was set up to energize a phonelescope. The pencil of light from the lantern was reflected from the phonelescope to a small mirror on an electrically-driven tuning fork of frequency 128, and thence to the screen. All the common Lissajous' Figures were readily produced by adjusting the condenser controlling the oscillator frequency.

The oscillator obviously should be nearly free from harmonics. A simple oscillator meeting this requirement for the low frequencies used, which can be assembled for the most part from standard laboratory equipment, was described.

42. Progress in Practical Meteorology.

By W. C. DEVEREAUX, U. S. Weather Bureau, Cincinnati, Ohio.

(Author's Abstract).

Just sixty years ago a man came to Cincinnati to take charge of the astronomical observatory, located at that time on the top of Mt. Adams. This man, Professor Cleveland Abbe, appears to have been more interested in meteorology than in astronomy. His work, at that time, in astronomy was soon forgotten; his work in meteorology lives on forever.

Fifty-six years ago the Signal Service of the Army devised a unique system of collecting and distributing weather reports. This system grew and expanded and was known as the circuit system. The weather messages chased each other around and over the country, dropping off a copy here and there as needed. Like the old "Circuit Rider" the system became obsolete.

At 8:00 A. M., April 1, 1928, an entirely new system became effective for collecting and distributing weather reports. The new system uses automatic apparatus, which admits of several channels of communication over a single wire. To accomplish these changes it became necessary to organize a new system for collecting and distributing river reports. At present all river reports made in the Ohio Valley are sent to Cincinnati and from here distributed to other stations, and a similar collecting and distributing center was established at St. Louis for the Mississippi Valley. The changes are the most extensive ever made in meteorological service. It seems quite appropriate today at a meeting of the Ohio Academy of Science in Cincinnati to explain this great progress in practical meteorology as the system of weather telegrams originated in Cincinnati sixty years ago. The first weather map ever published in this country was issued by Professor Abbe on February 2, 1869, at Cincinnati. Detailed weather reports are now sent from all large broadcasting stations, and condensed weather information, including forecasts are broadcast from 160 additional stations. At Cincinnati, complete river bulletins are put on the air each day and these bulletins are copied at dams on the river all the way from Pittsburgh to Cairo. A still newer development is the progress being made in adapting the meteorological service to the needs of aviation. All this service has been started in the last few years.

These are only a few of the things that the Weather Bureau is doing today. I do not have time to mention others. We claim that more progress has been made in developing practical meteorological service during the last few years than was ever before made in a similar period by any meteorological service.

43. The Postulates and Concepts of the Quantum Theory as Applied to Optical and X-Ray Spectra.

By S. J. M. ALLEN, University of Cincinnati, Cincinnati, Ohio.

(Author's Abstract).

Bohr's conception of the quantum theory, applied to the radiation from an excited atom, rests upon two postulates:

(a) That the frequency of radiation is given by $v_t = \dfrac{W}{h}$, where $W =$ the change of energy of the atom between the stationary and excited states, h being Planck's action quantum.

(b) That the energies in the stationary states have discrete values, governed by the quantizing condition that the associated angular momentum can change only by whole numbers of a fundamental quantity $\dfrac{h}{2\pi}$, i. e. $p = \dfrac{n\,h}{2\pi}$.

The meaning underlying these postulates appears to a reader as somewhat obscure. Also the action quantum by its dimensions is equivalent to work x time, a somewhat difficult concept in physics. If h is a universal constant, what is the nature of the work and time involved in it?

The following method of considering the problem is given by the author and seeks to furnish some meaning for the processes involved.

We will consider the total radiated negative energy of the atom to bear a definite numerical relation to that of the hydrogen atom (single electron and proton).

Thus, $W = NW_0$, W_0 —hydrogen energy, and N a number.

Also that the energy is radiated from all orbits in the same time, t secs. Then we have $\dfrac{W}{t} = \dfrac{N}{t} W_0$, where $N/t = \nu_t$.

This is due to the condition that all radiated quanta must meet a fixed relation, the fixed velocity of radiation in free space.

$$\therefore \nu_t 1 = C, \text{ and } \frac{N}{t} 1 = C.$$

For hydrogen $N = 1$, $1 = 911.76\text{Å}$, $C = 2.9998 \times 10^{10}$ cm/sec, whence $W_0 = 2.156 \times 10^{-11}$ ergs, $t = 3.040 \times 10^{-16}$ secs, and $W_0 t = 6.554 \times 10^{-27}$ erg-secs.

In order to fix the energy W to discrete values we make the one assumption

$$N = \frac{Z^2}{n^2}$$

where $Z =$ atomic number, and n the principal quantum number.

Then $W = \dfrac{Z^2}{n^2} W_0$ (W is the negatived energy).

For a central inverse square force system,

$$W = \frac{Ze^2}{2r}, \text{ where } r = \text{radius vector of the orbit.}$$

$$\therefore r = \frac{n^2}{Z} r_0, \text{ since } W_0 = \frac{e^2}{2r_0}.$$

It follows at once that

$$v = v_0 \frac{Z}{n}, \quad \tau = \frac{n^3}{Z^2} \tau_0, \text{ and } p = np_0$$

Also, $p = \dfrac{nW_0 \tau_0}{\pi} = \dfrac{nW_0 t}{2\pi}$

if $t = 2\tau_0$. This is equivalent to Bohr's quantizing condition, viz.,

$$p = \frac{nh}{2\pi} = \frac{n(W_0 \times t)}{2\pi}$$

This seeks to give a meaning (W_0 and t) to the somewhat unexpressed meaning in Planck's action h.

Consequently $W_0 t = h$.

The radiation equation follows at once

$$\nu = \frac{W_1 - W_2}{W_0 ct} = \frac{R(W_1 - W_2)}{W_0} = \frac{RZe^2}{2W_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = RZr_0\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{RZr_0}{r_1} - \frac{RZr_0}{r_2}$$

= Limit term minus sequence term.

In this conception the quantization of the terms may be expressed in terms of a unit radius vector r_0, and a quantum number n.

n is a whole number for a hydrogenic term, but not in general, being the same as $(m+\mu)$ in Rydberg's equation.

In any atom of more than one electron the value of n will depend on the negative potential energy of the orbital electron, diminished by the positive potential energy due to the repulsion outwards of the other electrons. Since these actions on account of the relative velocities will not be constant, the orbit of each electron will be a closed curve (circle or ellipse) having superimposed on it a fluctuating perturbation of a peculiar periodic character. The actual measured n in spectroscopic work will be an average value, and not a whole number.

The author discussed the optical spectra of neutral helium, lithium and the K absorption limits in X Rays, and showed that these latter apparently showed a Moseley diagram for isoelectronic systems (normal) which instead of being a straight line is a series of straight lines of different slopes, occurring at definite values of Z, where new groups are formed, such as, $Z = 3$, $Z = 11$, $Z = 19$, etc.

44. Dr. Hendrik Antoon Lorentz: A Tribute.

By MAXIMILIAN BRAAM, 3449 Lyleburn Place, Cincinnati, Ohio.

(Author's Abstract).

Dr. Hendrick Antoon Lorentz was born in 1853, in the city of Haarlem, the Netherlands. Early in life, he became interested in Mathematics and Natural Science, and even then, he showed marked ability in these fields. While he was still in the secondary school, he pointed out that "The Law of Snell, (Snellius)" could be derived from 'The Principle of Huyghens.' "

At the age of 19 when he had finished his undergraduate studies, he began teaching in the Evening High School, in Haarlem, his home city, while at the same time he pursued his studies for the doctor's degree.

Three years after he had taken his degree at the University of Leiden, he received the appointment of that university as Professor of Natural Science, he being, at that time, in his 25th year. In the course of time, he developed and formulated the theory of electrons and thereby prepared the way for the theory of relativity as developed by Einstein. In 1903, Lorentz, with Dr. P. Zeeman of the municipal University of Amsterdam, was awarded the Nobel Prize.

In 1912, having accepted the appointment as curator of the Teyler Laboratory for Research, at Haarlem, he remained connected with the University of Leiden as Professor Extraordinary.

The activities of Dr. Lorentz were not confined to the University of Leiden, nor to his country. He accepted many invitations to lecture in foreign countries. In Germany, he lectured at the University of Tuebingen; in France, at the Sorbonne; in England, at Cambridge, and in the United States at most of the greater universities.

On the 4th day of February, of this year, Dr. Lorentz, ripe in years, and rich in honors, with the calmness and fortitude of wisdom passed

from among the living. Many representatives of foreign universities were present at the funeral. Among them may be mentioned, Madame Curie and Dr. Langevin from Paris; Dr. Rutherford from Cambridge, and Dr. Einstein from Berlin.

The works of Dr. Lorentz have been translated into many foreign languages, even into Japanese.

45. The Structure of Space and Matter

By DR. R. M. MANLEY, Cleveland, Ohio.

(Author's Abstract).

Space is postulated as repellent points tending to move in straight lines in every direction with light-velocity, and matter as whorls of similar monads interfering with special movements. Hypothetical models illustrate the dynamic principles involved in the electron, proton, hydrogen and helium atoms congruent with principles required by Bohr's atom, the quantum theory, equivalence of mass and energy and relativity. Definitions assumed for space and matter demand light-velocity propagation of gravitational force; this, in turn, necessitates a variation in the action of gravitational force not hitherto emphasized, e. g., two bodies moving tandem fashion along the same path do not have like gravitational influences upon each other, the forward body exerting the greater influence; when considering intra-atomic particles moving at high velocities, this becomes a powerful factor capable of harmonizing many otherwise paradoxical phenomena and theories.

46. Basal Metabolism and Menstruation

By CHARLES G. ROGERS and JOAN FLEMMING, Oberlin College, Oberlin, O.

(Authors' Abstract)

In this paper, there is a general discussion of basal metabolism, followed by a discussion of the literature on the special phase of basal metabolism and menstruation. The relation between some of the endocrine glands and the menstrual cycle, with particular emphasis laid on the thyroid, is included.

The data from experiments on seven normal women, one non-menstruating woman, and one man are shown in graphs and tables. The graphs show the daily records and the averages for the four arbitary periods of the menstrual cycle. The tables show the pulse, respiration, and basal metabolic records in calories and percentages plus or minus, the sub-Dubois and the Harris-Benedict standards for each of the 103 tests and each subject's average for the periods of the month. The standard deviations and probable errors were calculated.

The results seem to show evidences of a relation between the basal metabolic rate and the menstrual cycle with the lowest point in the metabolic cycle coming during or immediately following the menstrual period. Evidence seems to be present also indicating a corresponding change in pulse and respiration rates. The non-menstruating subject showed very little change in basal metabolism and the man showed change but of a different kind.

47.   Medical and Public Health Work in a Large Coal Company.

By Dr. D. J. KINDEL, Fairmont, West Virginia.

(Author's Abstract).

The subject of this paper deals with the public health and medical work as carried on in industry by a large coal mining company.

The author points out that the company employed approximately fourteen thousand men located at their various operations in four different states.

Complete medical attention is given all employes and their families, a total aggregate number of people amounting to approximately sixty thousand.

To provide this service a staff of approximately thirty doctors, thirteen public health nurses, five dentists and a fifty bed hospital with a nursing staff is maintained.

It was brought out that the company is attempting to provide the best and most modern medical and nursing service for their employes and in order to do this the physicians and nurses care for no one but company employes.

The nursing activities were given briefly as follows: School Health Work, Health Study Classes and Groups, Clinics, Instructional House Visits, Immunizations against Typhoid Fever, etc., Tuberculosis Program, Correction of Defects, Elimination of Insanitary Conditions, Parent-Teacher Organization Activities, Social Work, Sanitary Surveys.

It was pointed out that the program was just beginning, scarcely a year old, and was begun by a sanitary survey including all the properties of the company.

In one division where typhoid fever was especially prevalent, thirty thousand typhoid inoculations had recently been given. The effect on the typhoid rate in the future is to be carefully watched.

A number of photographs were displayed illustrating the modern advancement in office equipment, health study clubs, clinic groups, etc.

THE BIOLOGY OF APPLE APHIDS.*

FRANK H. LATHROP.

INTRODUCTION.

Few groups of insects are of greater biological interest than
are the aphids. The occurrence of long series of partheno-
genetic individuals, interspersed at more or less regular intervals
with true sexual forms; the rapidity of reproduction; the presence
of both winged and wingless individuals; the precise selection
of host plants by the various species, and the remarkable
periodic migrations from one host plant to another; together
with the evident ecological basis for all of this complexity of
behavior, present many interesting problems in the field of
insect biology.

The studies upon which this paper is based were first under-
taken at the New York Agricultural Experiment Station
during the seasons of 1915 and 1916. During the fall and
winter of 1916, and the spring of 1917 the project was further
developed at Ohio State University. The investagitions were
later continued at the Oregon Agricultural Experiment Station.
While it has been attempted throughout to investigate the more
fundamental phases of the problem, the ultimate aim of the
work has been to broaden our knowledge of a group of trouble-
some and destructive pests. For this reason, and to avoid
scattering our efforts over too large a field, the studies have
been practically limited to the three most commonly injurious
species, the Rosy Apple Aphis, *Anuraphis roseus* Baker; the
Apple-Grain Aphis, *Rhopalosiphum prunifoiiæ* Fitch; and the
Green Apple Aphis, *Aphis pomi* DeGeer.

The writer takes this opportunity to express his indebtedness
to Doctor Herbert Osborn, Professor P. J. Parrott, and the late

Professor A. L. Lovett, for many kindly suggestions and much valuable assistance in the course of these investigations.

IMPORTANCE AND DISTRIBUTION OF THE SPECIES.

Aphids occupy a prominent place among the insect pests of our cultivated plants. This is no less true of apple than of other crops. In fact, next to the codling moth, aphids probably present a more generally serious problem to apple growers than does any other insect pest.

Owing to the variety of forms in which these insects occur, the complexity of host relationships, and to the inadequacy of many of the earlier descriptions, much confusion has arisen in the technical names applied to the species. Baker and Turner have made careful studies of the synonomy. The writer has not made a sufficient study of the taxonomy of the group to form an opinion of the value of their conclusions. However, as they have covered the field more thoroughly than any other workers, their conclusions have been accepted in this paper. It is to be hoped that their work will stand, and that further changes and confusion in nomenclature will be avoided.

Of the three species under consideration, the Rosy Apple Aphis is the most serious offender in bearing orchards, because of its characteristic attacks upon the developing fruit clusters, with the resulting deformation of the fruit. A severe infestation of young trees frequently results in a contortion of the shape of the entire tree.

The Green Apple Aphis, while capable of deforming the fruits in a manner similar to the preceding species, tends to confine its attacks to the more rapidly growing portions of the tree, and hence is primarily a pest of young plantings.

The Apple-Grain Aphis is primarily a pest of small grains, and has attracted more attention in that role than it has as a fruit pest. However, in some fruit growing sections it produces extreme infestation of the blossom clusters. Even in this case, however, the lack of toxicity to the apple tissues renders this species of rather minor economic importance.

In their excellent publication on *Aphis pomi*, Baker and Turner (2, p. 957-958) give an interesting review of the history and distribution of this species. It is evident that this aphid has been present in this country from the earliest days of apple growing. The species was undoubtedly introduced from Europe

on nursery stock, and it has spread throughout America coincidentally with the establishment of orchards in new sections.

The species is widely distributed throughout the world. Baker and Turner list it from Japan and Orange Free State, and further state that "it is rather remarkable that this species has not become even more widely spread, since it is typically a nursery species and in the egg state is easily transported on nursery stock." It seems probable to the writer that its distribution is more widespread than published records may indicate, and that close investigation would show it to be present in practically all apple growing sections of the world where the trees are of European origin.

The Apple-Grain Aphis seems to have been introduced coincidentally with the Green Aphis, and, as shown by Davis (5, p. 2), it seems to be equally widespread in North America.

The Rosy Apple Aphis was also introduced into this country early in the history of apple growing. Its spread has evidently been retarded to some extent by its dependence upon the alternate host plant, *Plantago lanceolata*, upon which the continued existence of the species is dependent. The correlation between the spread of this species and of *Plantago lanceolata* has been presented in an interesting way by Matheson (10, p. 721-724).

General Life Histories and Habits of the Species.

The life histories of the three species considered in this study have many points of similarity. All spend the winter as eggs on apple. These eggs hatch as the buds burst in the spring, and the aphids which emerge are apterous, agamic, viviparous females, termed stem mothers.

From these stem mothers there arise the later generations. The generations which follow contain both winged and wingless individuals. Throughout the summer, only viviparous agamic females are produced.

With the approach of fall, males and oviparous females are produced, and the over wintering eggs are deposited.

These characteristics are common to the life histories of the three species, but there are variations in the seasonal activities which will be taken up in the discussions of the several species.

KEY FOR DISTINGUISHING THE SPECIES.

I. Newly hatched nymphs of stem mothers, appearing on the bursting buds in early spring.

    A. Dark green, more or less covered with whitish pulverulence; several rows of tuberculate spots lengthwise of body; antennæ reaching nearly to bases of cornicles; cornicles relatively long, prominent; scattered infestation on fruit and leaf buds.................*Rosy Aphis*

    B. Dark green. Antennæ short, reaching to the middle pair of legs; cornicles extremely short, disc-like; scattered infestation on leaf and fruit buds......................................*Apple-Grain Aphis*

    C. Dark green, some individuals varying to lemon yellow; antennæ of intermediate length, not reaching bases of cornicles; cornicles short, conical in shape; typically occurs in dense colonies on water-sprouts and other terminal growths................................*Green Aphis*

II. Mature viviparous females on apple during spring and summer.

    A. Dark bluish slate color, varying to yellowish brown, usually more or less pulverulent; antennæ reaching to about the middle of the abdomen; cornicles long, somewhat curved, blackish; usually found in tightly curled leaves of fruit or leaf clusters.............*Rosy Aphis*

    B. Pale yellowish green in color with a series of transverse darker green spots, which together form a broad, deeply serrated, green band extending the full length of the abdomen; antennæ and cornicles relatively short; cornicles green or dusky in color; infesting fruit and leaf clusters, causing little or no curling of the foliage..*Apple-Grain Aphis*

    C. Bright green in color, varying to lemon yellow in some individuals; cornicles and cauda black in striking contrast with the bright green body; usually found in dense colonies on the more succulent tissues; moderate to severe curling of the foliage.................*Green Aphis*

III. Female migrants appearing on apple in early summer and in the fall; throughout the summer in the case of the green aphis.

    A. Antennæ reaching the bases of the cornicles; cornicles long, slender, slightly curved; lateral margins of the abdomen brownish, marked by three large black spots anterior to the cornicles; middorsum of abdomen black. The black markings are intensified in the fall migrants...*Rosy Aphis*

    B. Antennæ shorter, not reaching the bases of the cornicles; cornicles short and straight; abdomen soft green, a row of spots on lateral margins anterior to the cornicles; dorsum of abdomen without distinct black markings (or marked with rather indistinct black or dusky transverse bands on the dorsum of the abdomen in the fall migrants)...*Apple-Grain Aphis*

    C. Antennæ and cornicles intermediate in length, abdomen unmarked rich green varying to yellow in striking contrast to the black cornicles, cauda, and thorax.............................*Green Aphis*

IV. Males first appearing on apple foliage about the time the fruit matures in the fall.

    A. Winged; abdomen small, somewhat recurved under body, usually entirely black; otherwise resembling female migrant with its long antennæ and cornicles.....................................*Rosy Aphis*

    B. Winged; abdomen small, usually entirely black, somewhat recurved under body; otherwise resembling female migrant with its relatively short antennæ and cornicles.........................*Apple-Grain Aphis*

    C. Wingless, much smaller than the female of the species, antennæ reaching the bases of the cornicles; general color brownish, varying to olive; cauda and genitalia black.......................*Green Aphis*

V. Oviparous females, appearing on apple from the time the fruit matures until the leaves have dropped; wingless in all species and distinctly more elongate in form than the viviparous females.

    A. Antennæ reaching nearly to bases of cornicles; color nearly uniform pale yellowish, varying to greenish.......................*Rosy Aphis*

   B. Antennæ shorter, scarcely reaching beyond middle pair of legs;
     cornicles somewhat shorter than in preceding species; antennæ,
     legs and cornicles more dusky......................*Apple-Grain Aphis*
   C. Antennæ intermediate in length; color rich green varying to yellow
     with striking black cornicles and cauda....................*Green Aphis*

The Apple-Grain Aphis.

The eggs of this species are the first to hatch in the spring. The exact date varied with climatic conditions, but generally occurs as the apple buds begin to show green at the tips. Baker and Turner (2, p. 966; 4, p. 312) have found that the eggs of this species may hatch at any time after early January, providing climatic conditions are suitable. Such hatching frequently occurs in the vicinity of Washington, according to these authors. This premature hatching is, of course, ordinarily fatal to the nymphs that emerge. In western New York hatching ordinarily occurs during mid April, and in western Oregon observations show that hatching occurs in early March.

The tiny nymphs migrate to the developing buds where they proceed to suck their nourishment from the developing tissues. These stem mothers mature just as the blossoms begin to show pink. Rapid reproduction immediately after this period greatly increases the numbers of individuals in the colonies, and in Eastern fruit sections extreme infestation may occur. The tendency of this species to attack the blossom clusters, and the conspicuous infestation that frequently results gives this species one of its common names—The Apple-bud Aphis.

With the dropping of the petals, the winged forms begin their migration to the summer host plants. By the time the apples reach the size of marbles the apple is entirely deserted.

During the summer months reproduction is continued by agamic viviparous females on grains and grasses of various kinds, but the species seems to prefer oats when this is available.

With the approach of fall, female migrants fly back to the apple where they give birth to the oviparous females. Following this the winged males are produced, and these also migrate to the apple. As the oviparous females mature they are fertilized by the winged males.

After fertilization, the oviparous females become restless, leave the leaves where they were produced, and crawling down the stems seek places for oviposition. Oviposition takes place

as the leaves are dropping, and continues until the females are destroyed by frosts.

This species has a tendency to secrete the eggs about the buds, or in cracks, crevices, or irregularities of the bark, so that ordinarily they are not readily observed. When infestation is unusually severe however, the eggs may be plastered promiscuously over the stems and twigs of the infested tree in a manner more typical of *Aphis pomi*. The writer observed such colonies of eggs of the Apple-Grain Aphis at Columbus, Ohio, during the winter of 1915-16.

Not all of the aphids of this species migrate to the apple in the fall, and even in the colder sections of the country infestation may continue on grain throughout the winter months.

The Rosy Apple Aphis.

The eggs of this species hatch somewhat later than those of the preceding species, and the apple buds are in a slightly more advanced stage of development. The time between the hatching of these two species varies from one or two days to ten or fifteen days, depending upon climatic conditions.

As with the preceding species, the newly emerged nymphs at once seek the developing buds, where they are to spend their lives. The stem mothers mature as the blossoms are in the pink stage, at which time many of the aphids of this species will be found protected by the curling of the infested foliage.

The dropping of the petals marks the period of maturing of the second generation, and there is a great increase in the numbers of this species. These aphids tend to remain within the curled leaves of the parent colony until forced out by over crowding. When this occurs there is a marked increase in the centers of infestation in the tree.

With the development of the third generation winged forms appear. During mid June this species reaches its maximum abundance on apple, and after July first the decrease is rapid. The apple is practically deserted by the end of July, although isolated colonies may be found after this date.

During the summer months reproduction is continued by agamic viviparous females on the narrow leaf plantain.

With the approach of fall, migrants are produced which renew the infestation of the apple. As with the preceding species, these migrants are first mostly females which produce the oviparous females on apple, later the males predominate on

plantain.   These fly back to the apple and fertilize the oviparous females.

This species secretes its eggs in crevices of the bark of the branches or even the trunk of the tree.   Hence they are difficult to observe in any numbers.   Oviposition takes place as the leaves are dropping from the trees, and continues until frost destroys the females.

In the colder sections of the country this species has not been observed to overwinter on plantain, but in the mild climate of western Oregon, overwintering on plantain as well as apple is the rule.

The Green Apple Aphis.

This species is the last to hatch.   The exact date of hatching varies in different localities, but the buds are usually well advanced at the time of hatching.

As with the other species the newly hatched nymphs crawl to the developing buds, where they obtain their nourishment.   The eggs of this species are clustered in immense numbers on the terminal growths of the infested trees.   Accordingly, the initial infestation occurs in dense isolated colonies on the terminals.   With the development of the winged forms the infestation is scattered, and colonies arise throughout the orchards.

This species spends the entire summer upon apple.   With the approach of fall, males and oviparous females are produced. Oviposition begins with this species much earlier than in the case of the other two species, and in early September, about the time the fruit matures, the first eggs may be found.   Egg laying continues until the females are killed by cold weather.

SEASONAL SUCCESSIONS OF THE SPECIES.

Observations at Geneva, New York, (12, p. 37–39) showed that the relative abundance of the three species of aphids concerned in these studies passes through a seasonal cycle or succession that seems to be fundamentally constant in all of the sections in which these studies have been continued.

Activities begin with the hatching of the Apple-Grain Aphis just as the first green shows at the tips of the developing apple buds.   This is followed by the hatching of the Rosy Aphis. The Green Aphis is the last to hatch, and the apple buds are usually well advanced by this time.

The "stem-mothers" of the Apple-Grain Aphis begin to give birth to living young just as the apple blossoms are showing pink. Rapid reproduction immediately after this period soon greatly increases the numbers of this species, and in regions where it commonly infests apple it rapidly becomes by far the most abundant species.

Very shortly after the maturing of the stem-mothers of the Apple-Grain Aphis, those of the Rosy Aphis and the Green Aphis mature. The dropping of the petals marks the time of maturing of the second generation of the Rosy Aphis, and about this time the Apple-Grain Aphis begins its migration to its summer host plants. While the Apple-Grain Aphis is becoming less abundant because of migration to the summer food plants, reproduction by the second generation of the Rosy Aphis greatly increases the numbers of this species, so that during the interval extending from about the middle to the last of June the Rosy Aphis is the more abundant of the two species.

After July first, migration of the Rosy Aphis is rapid and by the latter part of the month this species has practically deserted the apple. While the Rosy Aphis is decreasing in numbers, the Green Aphis is establishing new centers of infestation in the orchard and, under favorable conditions, the species increases rapidly. By the end of July, the Green Aphis is the only one of the three species remaining on apple, and this condition continues throughout the rest of the summer.

With the approach of fall, the males and oviparous females of the Green Aphis are produced and eggs usually appear as the winter apples ripen. About the time the fruit matures, winged female migrants of the Rosy Aphis and the Apple-Grain Aphis return to apple where they produce the oviparous forms. Later the winged males of these two species migrate to apple, where they fertilize the oviparous females. Eggs are deposited as the leaves are dropping.

REGIONAL VARIATIONS IN BEHAVIOR.

These studies, made in districts so widely separated and so distinctly different in climate, have brought out several interesting facts relative to the regional variations in the behavior of apple aphides. A report (6) on this phase of the work has been published in the *Journal of Economic Entomology*.

Relative Abundance of the Species.

Probably the first difference to be noted is the relative abundance of the several species in the two regions.

In western New York the Apple-Grain Aphis is normally the most abundant of the three species. Although the actual injury from this species is slight because of its low toxicity upon apple, the species, nevertheless, produces a heavy and conspicuous infestation, especially upon the blossom clusters, where it occurs in enormous numbers.

In the fruit districts of the Willamette Valley, Oregon, this species is rare upon apple, and each spring a thorough search has been necessary in order to find even a single colony in any of the orchards in which examinations were made. Apparently this same condition applies in California (17, p. 94). However, the species occurs more or less commonly on grains and grasses in both Oregon and California. This seems to indicate that the species is not conspicuous as an apple pest in regions where the climate permits wintering on grains and grasses. This accords with observations by Davis (5, p. 10), who finds that in the southern part of the United States this species may winter entirely upon grains and grasses, no eggs being deposited upon apple.

Next to the Apple-Grain Aphis, the Green Aphis is the most abundant in apple orchards of western New York. This species increases in abundance during midsummer and young plantings as well as the more succulent portions of mature trees frequently suffer severe injury.

In western Oregon, the Green Aphis is by no means uncommon, but severe injury from this species is not of frequent occurrence. The greatest abundance occurs in early summer; later in the season, infestation usually subsides to a minimum.

The Rosy Aphis is by far the most common species in western Oregon, while in western New York, it is ordinarily the least numerous of the three. Because of the high toxicity of this species upon apple, and because of its habit of malforming the fruit, this is a serious pest wherever it occurs. The great abundance of this species under normal conditions in western Oregon ranks this insect with the codling moth as one of the major pests of the apple.

Hatching.

Spring advances rapidly in western New York with a proportionally rapid hatching of the eggs of the aphids under consideration. The gradual approach of spring in western Oregon is accompanied by a long hatching period. There is a corresponding and even more striking prolongation of the intervals between the hatching periods of the several species.

During the spring of 1916, the Apple-Grain Aphis began hatching in the locality of Geneva, N. Y., on April 22; the Green Aphis on April 26, a difference of four days. The Rosy Aphis was intermediate between the two, but there was so little difference in time that the hatching of the first two species appeared to occur almost simultaneously. Baker and Turner (2, p. 966), working at Vienna, Virginia in 1915, observed a difference of eleven days between the beginning of the hatching period of the Apple-Grain Aphis and that of the Green Aphis Peterson (13, p. 366), studying these species in New Jersey in 1919 observed a difference of fifteen days between the beginning of the hatching periods.

In western Oregon, the hatching of the Green Aphis begins from nine to fifteen days later than the Rosy Aphis. The extreme scarcity of the Apple-Grain Aphis in the orchards under observation here has made it impossible to determine the exact date of hatching; however, it occurs certainly from ten to fifteen days prior to the hatching of the Rosy Aphis. This makes an interval of from nineteen to thirty days between the hatching of the Apple-Grain Aphis and the Green Aphis.

The length of the hatching period shows a similar regional variation. Baker and Turner record a period of seventeen days between the hatching of the first and last eggs of the Green Aphis in Virginia. At Geneva, N. Y., (12, p. 37) in 1916, hatching began on April 26 and was completed by May 2, a period of six days. At Corvallis, Oregon, in 1921, the eggs upon one tree under observation began hatching March 20, and continued to hatch until April 18, a period of twenty-nine days.

Summer Activities.

The most pronounced regional difference noted in the behavior of these aphids during the summer months occurred in the time of appearance of the winged forms.

At Geneva, N. Y., in 1916, the second generation of the Apple-Grain Aphis consisted entirely of winged individuals, and the species quickly disappeared from the apple. Baker and Turner (4, p. 314) reported 89.1 per cent of the second generation winged at Vienna, Virginia in 1915. At Corvallis, Oregon, in 1919 the winged forms were very few in the second generation. They became predominant in the fourth generation.

The Rosy Aphis also shows a tendency to delay the production of winged forms, which accounts to some extent for the more serious nature of the pest under western Oregon conditions.

The Green Aphis shows a tendency in this same direction under Oregon conditions. Baker and Turner (2, p. 977) found that "in the second generation, the winged form outnumbers the wingless" in Virginia. During the spring of 1916, the writer observed colonies at Geneva, N. Y. in which at least ninety per cent of the second generation developed wings. This high percentage of winged forms in the second generation seems characteristic of the Green Aphis under Eastern climatic conditions. The scarcity of winged forms in the later generations is equally characteristic.

Observations in western Oregon show that there is much less tendency to thus segregate the development of winged forms. In this section, winged forms are usually not numerous in the second generation, but are much more common in the later generations than is the case in the East.

Winter Activities.

The hibernation of *Aphis pomi* as observed in Oregon shows no conspicuous variation from the behavior of the species elsewhere.

The Apple-Grain Aphis in western Oregon winters principally as viviparous females on grains and grasses, where growth and reproduction take place during the winter months when the temperature permits. Comparatively few migrants appear on apple in the fall, and hibernation in the egg stage on apple is uncommon.

The Rosy Aphis in western Oregon produces numerous migrants which return to the apple in the fall, and are normally sufficient to produce a severe infestation. However, in this section, only a portion of the plantain forms become winged in the fall. A considerable percentage remain on plantain through-

out the winter months. Reproduction and growth continue during the winter, although reduced to a very low rate. Specimens born in the insectary at Corvallis, November 27, matured February 10—a developmental period of seventy-four days.

Wintering on plantain is apparently normal with this species in the climate of the Willamette Valley, for infestation has been observed in the field throughout every winter from 1917 to 1921. During the winter of 1919–20, the Rosy Aphis on plantain in the field, where protected by snow, withstood a temperature of thirteen degrees below zero. Where there is no protection the species succumbs to a much less rigorous temperature.

With the approach of spring, the overwintering forms on plantain become more active, and winged forms are produced to spread the infestation.

Economic Aspects of Regional Variations.

The effects of regional variations in the behavior of apple aphids are of direct significance to the commercial fruit grower. The more severe injury to apple orchards normally resulting frcm attacks of the Rosy Aphis in western Oregon, makes the control of this pest in this section even more imperative than in regions where injury is less pronounced.

As a rule, the Green Aphis is less injurious in orchards of western Oregon than in New York fruit districts, and in normal seasons causes the western Oregon orchardist little concern.

The Apple-Grain Aphis is of no importance as an apple pest in western Oregon.

By wintering on plantain, the Rosy Aphis becomes independent of apple in western Oregon. The continuous breeding on plantain produces a source of supply of these insects, which serve as a reservoir for the species, and which accounts in part for the greater infestation of apples in this region. Any campaign which might be undertaken for the actual eradication of the species from western Oregon would have to be waged against the plantain forms as well as the infestation on apple.

In western Oregon the greater capacity of the Green Aphis for dispersal in the later generations would probably greatly interfere with the control of this species during seasons of unusual abundance.

The most unfortunate effect, however, of the regional variations noted is the failure of the standard "delayed dormant" treatment to successfully control the rosy aphis in western

Oregon in spite of the success with which this treatment is applied in the East. The unsatisfactory results which are attending the use of the "delayed dormant" spray of nicotine suffate for the control of this species in the Willamette Valley are probably due to the long-drawn-out hatching period more than to any other factor.

Feeding Habits.

As soon as the young aphids emerge from the eggs, they migrate to the developing buds. Ordinarily the nymphs may be found on the buds within twenty-four hours after hatching, but occasionally during inclement weather, young nymphs may be found secreted about the bases of the buds, apparently in a more or less inactive condition until weather conditions become more favorable.

With the separation of the leaves in the developing buds, the tiny aphids creep downward about the bases of the out-pushing foliage. Here these creatures are very well sheltered from wind and rain, as well as from sprays that may be applied to the trees.

As the developing leaves take form, the aphids assume positions on the under surfaces. As the numbers of aphids increase it may be noted that the tendency is to feed upon the midrib and main tracheal branches of the leaves, and the aphids will be found arranged along the main veins of the leaves. This is especially true of the rosy aphis and the oat aphis, both of which tend to remain upon mature leaves, where the colonies were originally established. In the case of the green aphis the tendency is to follow the growing tips of the plant, and thus feed upon the more succulent tissues. The tender, elongating stem as well as the foliage often becomes coated with the insects.

The young nymphs of all of the species have more or less tendency to migrate, especially when the parent colonies are overcrowded. These migrating nymphs usually seek the young, tender, more succulent leaves, where they establish new colonies.

ECOLOGICAL STUDIES.

The evident suspectibility of aphids to climatic influence, and the unusual degree to which the behavior of these insects is directly regulated by environmental conditions, make ecological studies of this group of especial interest and value.

General Influence of Environment.

The activities of aphids seem to an unusual extent to be directly regulated by environmental influence. The number of generations occurring during the season seems to be entirely dependent upon whether or not conditions are favorable for the rapid development of the insects. The time of production of winged forms seems to be dependent upon conditions of climate and the stage of development of the host plants. The development of gamogenetic forms seems to be dependent upon ecological conditions, and when coditions are suitable for the continued parthenogenetic reproduction, their production may be reduced or entirely omitted.

Undoubtedly, the response of these aphids to the varying conditions of environment is directed by the inherent tendencies of the species. The extent to which the seasonal cycles of aphides are hereditary, and the degree to which they are influenced by environmental factors has not been determined. Some workers, Uichanco (19), Tannreuther (18), place great emphasis on the hereditary influence. Our observations upon the species under consideration indicate that the inherent tendencies of the species directs the nature of the response, but the stimulus is supplied by environmental phenomena. Thus the gamogenetic forms are produced in all generations which survive until fall and which are influenced by appropriate environmental conditions. In the East the second generation of *Rhopalosiphum prunifoliæ* usually consists predominantly of winged migrants. Under the different environmental conditions of western Oregon, winged forms do not predominate until the fourth generation. This same tendency was shown in this species grown under greenhouse conditions at Geneva, New York; indicating that the time of production of winged forms is a reaction to environmental influence rather than an incident in a definitely inherited seasonal cycle.

Besides the effects of the physical environment, aphids are profoundly influenced by their associates and enemies. These have chiefly to do with the protection or destruction of the forms present. Attacks of natural enemies during early summer materially hastens the vacation of apple by the migratory species. These relations of the aphids to their organic environment are probably no less complex, and are equally as interesting as the reactions to the physical environment.

Analysis of the Environment of Apple Aphides.

In studying the environmental influences affecting plants, Livingston (9, p. 421) emphasizes the fact that while environmental conditions may be separated into groups, the different kinds of conditions do not influence the organism separately, but the entire complex of conditions acts as a unit in its influence upon the organism. While this is undoubtedly true, it is nevertheless possible and profitable to analyze the environmental complex, and to study the component factors, much as a chemist studies the elements which unite to form a chemical compound.
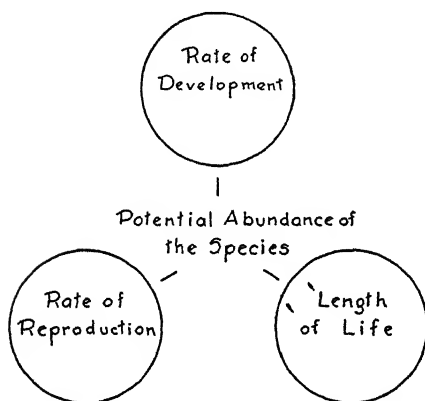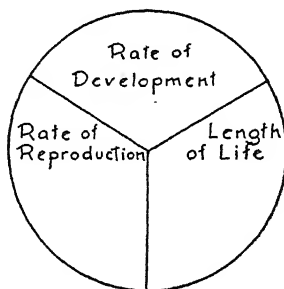
Fig. a.   Fig. b.

In order to make such an analysis of the environmental complex, it seems desirable first of all to consider the life processes of the organism which are influenced by the environmental factors considered. In the case of our three species of apple aphids, the potential abundance of the organisms may be regarded as depending upon three major phenomena: length of life, rate of reproduction, and rate of development. This may be represented diagramatically as in Fig. a, and may be condensed into Fig. b.

In studying the environment, it will be found that there are many interrelations between the several environmental factors themselves as well as the direct influences of the various factors upon the organisms. These interrelations between the environmental factors result in many indirect influences upon the organism, which may be less obvious, but are often of even greater importance than the direct influence of any given factor.

Thus if we consider the factor of Temperature, we find that the temperature of the atmosphere at any time is influenced by a number of other factors. This may be represented diagramatically:
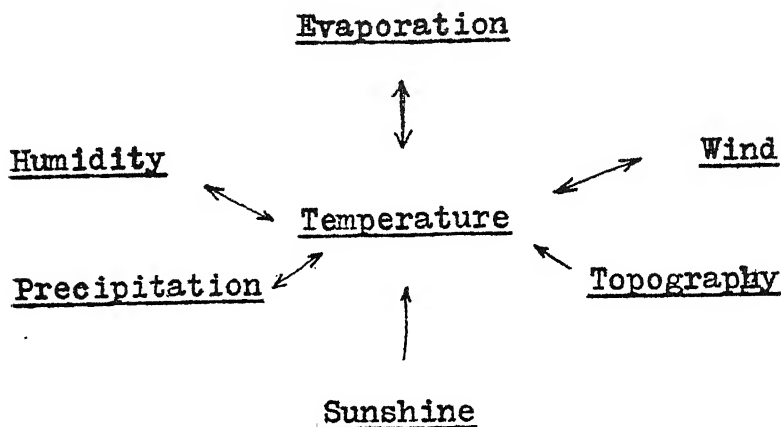
Evaporation

Humidity   Wind

Temperature

Precipitation   Topography

Sunshine

Fig. c.

It will be noted—as indicated by the arrows in the diagram—that in several instances the influence is reversable, the factors having reciprocal effects upon each other. It is readily realized that a complete grouping of the physical factors of the environment would show an almost endless number of such inter-factoral influences. It has been attempted to show such an arrangement diagramatically in Fig. d.

It will be noted that a number of factors which are important in their influence upon the environment, have little or no direct influence upon the activities of the organism.

The nature and degree of the response to any influence of the environment is determined and directed by the inherent tendencies of the organism. Hence, the influences of the environmental factors may be regarded as acting through the inherent tendencies of the organism as shown in the diagram.

The diagram is not to be considered as attempting to show exhaustively all the interrelations of the factors of the environment. Other factors may be added and changes will suggest themselves to the reader. The diagram does, however, indicate in a graphic and interesting way the extreme complexity and the great delicacy of the environmental relations.

Studies of Certain Environmental Factors.

It was attempted to study in detail the influence of some of the more important environmental factors. While these studies are not exhaustive, data have been collected which are interesting. In order to concentrate the study, most of these investigations have been centered upon *Aphis pomi*.
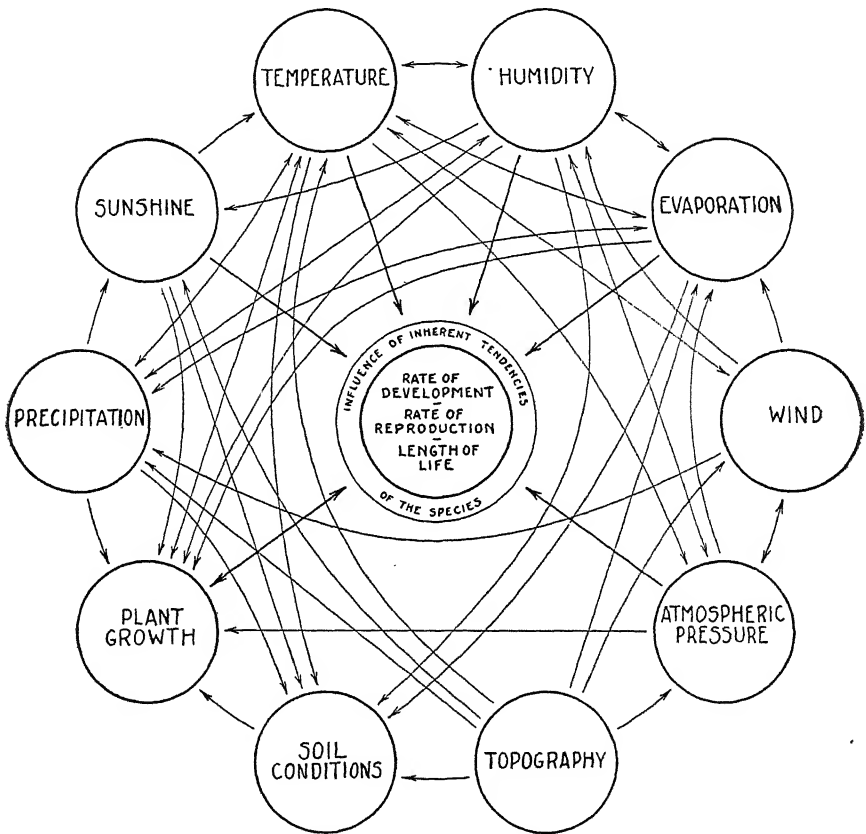

Fig. d.

A. Evaporation.

During the summer of 1919 and again in 1920, experiments were conducted in the hope that the measurement of atmospheric evaporation—combining, as it does, effects of both temperature and humidity—might, under normal outdoor conditions, give a fairly accurate index to the rate of metabolism of our apple aphides.

This work has been entirely in the nature of a field study and no attempt was made to modify or control the conditions of temperature or moisture.

The experimental plot was located on the college farm at Corvallis, Oregon, about one mile from the Agricultural Building, and had an elevation of approximately 225 feet above sea level. This plot consisted of one and two-year-old Greening apple trees planted in two rows about four feet apart with the trees about three feet apart in the rows. To the westward about sixty to seventy-five feet distant there was a dense growth of alders along the banks of Oak Creek. These trees, being some thirty-five feet in height, served to break the force of the strong, westerly "sea-breezes" prevalent during the summer months.

As the aphid eggs hatched, numbers of the nymphs were transferred to suitable buds on the experimental trees, and here allowed to mature. To obtain nymphs of the later generations, a number of adults would be placed on a suitable aphid-free leaf cluster. The following day these adults were removed, and the nymphs born during the twenty-four-hour-period were allowed to remain. These nymphs were permitted to mature in order to obtain the length of the developmental period. The developmental period was reckoned from the day after birth till the day of the appearance of the first young, inclusive.

The trees upon which the experiments were being conducted were protected by a special type of cage. This consisted of a cylinder of galvanized wire cloth, open at one end. To the open end of this cage was attached a cheesecloth skirt. The cage was inverted over the tree, and held in position at the proper height by means of a stake set nearby. The cheesecloth skirt was gathered about the trunk of the tree and tied with a cord. A band of cotton batting placed at the proper height on the tree rendered a perfect fit between the cloth skirt and the tree, and prevented binding of the trunk from the tie-cord. This type of cage is easily removed for examination of the aphids; is as readily replaced, and has proved quite satisfactory for this work.

The evaporation records were obtained by means of a "non-absorbing" evaporimeter or atmometer similar to instruments used in many evaporation studies by various workers during recent years. Standardized, spherical, porous, porcelain cups were obtained from the "Plant World," and results

as here given should be comparable with results obtained elsewhere by means of similar instruments.

Observations were made daily at 9:30 A. M.   The amount of evaporation was determined by filling the evaporimeter at this time.   A graduated pipette was used and readings were made to tenths of c.c's.

TABLE I.

Relation of Evaporation to Rate of Development of *Aphis Pomi* DeGeer. Summary of Data for 1919 and 1920.

Length of Developmental Period Days.	Average Total Evaporation for Period, c. c.	Average Daily Evaporation c. c.	Number of Records.
36	453.9	12.6	1
29	342.5	11.8	1
24	392.5	16.4	1
22	406.6	18.5	1
19	412.6	21.7	1
18	. 408.0	22.7	2
16	294.0	18.4	1
15	265.3	17.7	6
14	236.5	16.9	10
13	256.9	19.7	10
12	265.8	22.1	8
11	266.2	24.2	15
10	305.2	30.5	14
9	284.2	31.6	14
8	252.4	31.5	5
7	262.3	37.5	2

A study of the data presented in Table I shows that there is a general correlation between the rate of evaporation and the rate of development of *Aphis pomi*.   On the whole, a high rate of evaporation was accompanied by a rapid development of the aphids; and a low rate of evaporation, by a comparatively slow development of the insects.   While this correlation seems to be true in a general way, there is considerable variation from the mean.

These results show that under the condition of this investigation, evaporation, as registered by the standard evaporimeter used, is not a satisfactory measure of aphis metabolism. This condition apparently results from the fact that the combination of factors—humidity, temperature, wind, etc.—which influence evaporation, affect evaporation from the standard porous cup in a manner which is not closely comparable to its effect upon the metabolism of *Aphis pomi*.

As pointed out by Livingston (8, p. 127) the rates of evaporation from different types of evaporimeters under any given complex of atmospheric conditions are not comparable. It is, therefore, not surprising that evaporation from an instrument as used in these experiments would not give an accurate index of the effects of the atmospheric conditions upon aphis metabolism. It is possible that an evaporimeter more closely simulating the conditions of the aphid body might give a closer correlation between atmospheric evaporation and insect metabolism.

B. Temperature.

During the summers of 1920 and 1921 experiments with *Aphis pomi* were continued, and accurate records of temperature were kept in an attempt to learn the influence of this factor in the development of the species.

In general the procedure was similar to that described under the study of Evaporation. The temperature records were obtained by means of a Tycos Dial Type Mercury Recording Thermometer, manufactured by Taylor Instrument Companies, Rochester, New York. The daily mean temperature was determined by reading the temperature on the charts for each half hour, and averaging these forty-eight readings. The mean temperature for any given period of days was obtained by averaging the daily mean temperatures.

The actual mean temperature of the developmental periods of the several series were first plotted on a graph. It was found that those points lie approximately along a hyperbolic curve having the formula* $x = \dfrac{a}{y-b}$. This formula may be expressed: length of

$$\text{developmental period in days} = \frac{180}{\text{Temperature in degrees F} - 41}$$

*The writer is indebted to Professor E. B. Beaty of the Department of Mathematics, Oregon Agricultural College, for the computation of the formula for this curve.

If the curve thus plotted be extended it will be found that as the temperature is lowered, the development of the aphids becomes less rapid, until, at a temperature of 41°F or less, development ceases entirely. In other words, only temperatures above 41°F are "effective" (16, p. 114, 116) in the development of *Aphis pomi*. By subtracting all temperatures of 41° or less, and by computing the mean of the remaining temperature readings, the mean effective temperatures were obtained.

TABLE II.

Relation of Temperature and Evaporation to Rate of
Development of *Aphis Pomi* DeGeer, 1920.

Aphid Series Number	Date of Birth	Date First Young Produced	Developmental Period, Days	Total Evaporation, c. c.	Average Daily Evaporation, c.c.	Mean Temperature, ° F.	Duration Effective Temperature, Days	Mean Effective Temperature, ° F.
1	Mar. 28	May 3	36	453.9	12.6	45.1	23.3	49.7
2	May 3	May 16	13	312.4	24.0	52.6	10.4	57.4
3	May 13	June 1	19	412.6	21.7	51.3	14.5	56.5
4	May 16	June 3	18	406.0	22.6	51.6	13.9	56.5
5	May 31	June 12	12	249.1	20.8	56.8	11.6	57.3
6	June 2	June 16	14	231.5	16.5	55.9	13.3	56.2
7	June 9	June 21	12	216.8	18.1	57.5	11.4	58.1
8	June 14	June 27	13	324.0	24.9	57.5	12.2	59.6
9	June 17	June 27	10	274.7	27.5	58.2	9.5	60.0
10	June 21	June 30	9	238.1	26.5	59.5	8.6	61.8
11	June 27	July 6	9	265.3	29.5	64.5	8.7	65.7
12	June 30	July 9	9	302.7	33.6	63.8	8.7	63.9
13	July 7	July 18	11	218.8	19.9	61.1	10.9	61.3
14	July 9	July 18	9	166.7	18.5	61.0	9.0	61.1
15	July 18	July 28	10	273.6	27.4	62.5	9.8	62.7
16	July 28	Aug. 6	9	226.1	25.1	64.5	8.0	66.1
17	Aug. 12	Aug. 23	11	368.7	33.5	63.8	10.7	64.5
18	Aug. 20	Sept. 2	13	298.6	22.9	59.3	12.0	60.2
19	Aug. 20	Sept. 11	22	406.6	18.5	57.6	20.5	58.6
20	Aug. 23	Sept. 2	10	212.9	21.3	57.5	9.0	59.8

By subtracting from the developmental period, the time during which the temperature was 41° or less, the duration of effective temperature was determined.

In general, the records as plotted on the graph do not coincide exactly with the theoretical curve of development. This is no doubt due largely to the fact that observations of the aphids were made only once daily, which would tend to cause a lagging in the recorded rate of development of the insects. Toward the end of the growing season, the development of the aphids in some of the series was retarded to some extent by the

lack of succulence of the plant tissues, in spite of the fact that the most succulent growing tips were selected for rearing the aphids. The extent to which development may be retarded by such a limiting factor is shown by series 19 (Table II), which was reared upon mature foliage. For its development this series required a period of effective temperature of 20.5 days although accompanied by a mean effective temperature (58.6°) high enough to permit development in half the time consumed. This effect of the growth of the plant upon the development of *Aphis pomi* was also noted by Baker and Turner (2, p. 982-984) who regard it as a food relationship. It is evident that the condition of the foliage of the food plant frequently constitutes a limiting factor of considerable importance to the activities of *Aphis pomi*.

THE REPRODUCTION OF APHIS POMI.

Influence of Age upon the Number of Nymphs Produced.

During the studies of these aphides it has been noticed that for a period immediately after maturity, the number of nymphs produced each day was usually considerably larger than was the case later in the life of the adult. Toward the end of the life of the aphid, the number of nymphs produced was still further reduced, and finally, immediately preceding death, several days would frequently elapse with no reproduction.

In Table III is shown the reproduction records of a number of lots of Aphis pomi during the summer of 1921. These lots were selected because of the fact that at least some individuals in each lot completed their normal period of life. The periods covered by these lots extended through most of the summer, thus obviating the effects of temperature and other factors.

It will be noted that the daily reproduction continued at quite an uniform rate for a period of sixteen days. During this period the average number of nymphs produced per adult per day was 3.23. The highest average for the series for any day was 3.87; the lowest 2.76. This was followed by a period of four days during which an average of 2.29 nymphs per day. The highest average for this period was 2.51; the lowest 2.13. During the next period of three days a daily average of 1.55 nymphs per adult was produced. In this period the highest average was 1.66; the lowest 1.47. Following this, beyond the twenty-third day of adult life, a daily average of less than one

TABLE III.

The Effect of Age upon the Number of Nymphs Produced by *Aphis pomi*.

Age after Maturity Days	1		2		3		4		5		6		7		8		9		10		11	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
Lot No. 4	24	12	30	10	27	8	34	7	22	7	7	7	17	6	21	6	21	6	17	6	17	6
5	11	6	22	6	5	5	11	5	21	5	21	5	15	5	15	5	24	5	19	5	33	5
6	1	3	4	3	9	2	9	2	2	2	5	2	6	2	5	2	11	2	10	3	19	3
10	40	10	44	10	20	10	33	9	22	8	29	8	27	8	26	8	28	8	30	8	30	8
11	72	15	57	15	29	10	21	8	55	8	28	8	29	8	25	7	21	7	15	7	25	6
12	46	7	30	7	30	7	48	7	27	7	18	7	26	7	26	7	23	7	22	7	24	7
15	25	10	40	10	40	10	44	10	46	10	37	9	37	9	41	9	38	9	38	9	36	9
16	30	10	45	10	43	10	50	10	28	10	29	10	33	10	33	10	38	10	27	10	36	10
18	66	10	37	11	36	11	34	11	43	11	47	11	37	11	36	11	35	11	34	11	52	11
31	40	12	37	12	38	12	41	12	42	12	19	12	32	12	25	12	38	12	39	12	32	11
32	16	13	36	14	36	14	56	14	31	10	20	10	26	10	13	10	26	10	26	10	30	10
33	30	10	60	10	41	11	19	11	36	11	17	11	26	11	26	11	33	11	28	11	51	11
36	12	10	33	10	34	10	10	8	21	8	21	8	20	8	19	8	27	8	23	8	21	8
Totals......	413	128	475	128	388	120	410	114	396	109	298	108	331	107	311	106	363	106	328	107	406	105
Av. per Adult.....	3.23		3.71		3.23		3.60		3.63		2.76		3.09		2.93		3.42		3.07		3.87	

TABLE III—Continued.

Age after Maturity Days	12		13		14		15		16		17		18		19		20		21		22	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
Lot No. 4	25	6	17	6	26	6	30	6	38	6	26	6	16	6	15	6	6	5	7	5	6	5
5	25	5	36	5	21	5	17	4	18	4	8	4	4	3	5	3	5	3	5	3	5	3
6	10	3	11	3	14	3	13	3	7	3	3	3	3	3	3	3	7	3	2	3	1	3
10	16	8	20	8	20	8	35	8	29	8	26	8	24	8	15	7	17	7	17	7	14	7
11	25	6	26	6	30	6	18	6	21	5	16	5	18	5	18	5	16	5	10	5	14	5
12	18	7	24	7	27	7	27	7	22	7	14	7	31	7	17	7	24	7	7	7	6	6
15	34	9	13	9	14	9	28	9	18	8	9	6	18	6	9	6	0	1	0	1		
16	13	10	12	10	11	10	20	8	19	9	28	9	20	9	30	7	30	7	13	7	14	7
18	45	11	23	10	30	7	39	7	35	7	34	7	12	7	13	7	18	7	2	7	6	7
31	32	11	35	9	15	8	21	8	18	8	18	8	8	8	11	8	14	8	17	8	5	7
32	25	10	46	10	34	10	31	10	19	10	19	10	17	10	19	10	19	10	21	·10	20	10
33	34	11	40	11	26	11	27	11	19	11	21	11	21	11	23	11	22	11	20	11	19	11
36	27	8	28	8	13	8	18	8	23	8	9	8	13	8	9	8	9	8	15	8	11	8
Totals......	329	105	331	102	281	98	324	95	286	94	231	92	205	91	187	88	187	82	136	82	121	79
Av. per Adult.....	3.13		3.25		2.87		3.41		3.04		2.51		2.25		2.13		2.28		1.66		1.53	

In Table III, "A" indicates the number of adults present in each lot; "N" indicates number of nymphs produced.

TABLE III—Continued.

Age after Maturity Days	23		24		25		26		27		28		29		30		31		32		33	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
Lot No. 4	5	5	5	5	0	5	0	4	1	4	0	3	0	1	0	1						
5	2	3	0	3	1	3	2	3	0	3	1	3	0	3	0	2	0	2	0	1	0	1
6	9	3	3	3	3	3	5	3	3	3	2	3	2	3	4	3	0	2	0	2	0	2
10	16	7	6	7	2	7	2	7	6	7	6	7	2	7	1	7	1	7	0	7	0	6
11	7	5	8	5	5	5	5	5	2	5	2	5	6	5	6	5	6	5	0	5	0	5
12	3	6	1	6	0	6	0	4	1	4	0	4	0	4	0	4	0	3	0	2		
15																						
16	14	7	4	7	7	7	7	7	7	7	16	7	2	7	0	7	0	7	0	7	0	7
18	2	7	3	7	2	7	1	7	0	7	2	7	0	7	0	7	0	4	0	4	0	3
31	5	7	3	7	8	7	5	7	3	7	3	7	2	7	2	7	1	7	5	7	3	7
32	17	10	17	10	18	10	16	10	19	10	15	10	7	10	9	10	9	10	8	10	3	10
33	19	11	14	11	15	11	8	11	11	10	9	10	8	10	3	8	4	8	2	6	2	5
36	17	8	7	8	9	8	8	8	9	8	4	8	6	8	2	8	2	8	2	7		
Totals......	116	79	71	79	70	79	59	76	62	75	60	74	35	72	27	69	23	63	17	58	8	46
Av. per Adult.....	1.47		0.90		0.89		0.77		0.83		0.81		0.49		0.39		0.37		0.29		0.17	

TABLE III—Continued.

Age after Maturity Days	34		35		36		37		38		39		40		41		42		43		44	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A
Lot No. 4																						
5																						
6	0	1	0	1	0	1	0	1	0	1	0	1										
10	0	6	0	4	1	4	0	4	0	4	0	4										
11	4	5	0	3	1	3	1	3	0	2	0	1	0	1	0	1	0	1	0	1		
12																						
15																						
16	0	7	0	6	0	6	0	3	0	1												
18	0	1	0	1																		
31	1	7	0	7																		
32	0	10	0	10	0	10																
33	2	5																				
36																						
Totals......	7	42	0	32	2	24	1	11	0	8	0	6	0	1	0	1	0	1	0	1		
Av. per Adult.....	0.17		0		0.08		0.09		0		0		0		0		0		0			

In Table III, "A" indicates the number of adults present in each lot; "N" indicates number of nymphs produced.

nymph per adult was produced.   After this time the number of nymphs grew steadily less until reproduction ceased entirely.

The longest reproduction period occurred in the case of Lot. No. 11, which extended over a period of 37 days.   Incidentally the record for longevity also occurred in this lot—one individual living for a period of 43 days after maturity.

The Influence of Environmental Factors upon the Rate of Reproduction.

The number of nymphs which can be produced in a day by one female is distinctly limited by her inherent capacity for reproduction.   Thirty-six nymphs produced by five adults, an average of 7.2 per adult is the highest record for these studies.

Matheson (10, p. 700) found the greatest number of nymphs to be produced by one female to be thirteen, and this occurred in only one instance throughout his studies.   Baker and Turner (2, p. 973) give 16+ as the largest number of nymphs produced by one female in one day.   However, such cases are exceptional and the capacity of the average female is much less.   Because of this inherent limitation of the number of nymphs produced, there is considerably less possibility for the rate of reproduction to be influenced by environmental factors.

The results of these investigations indicate that temperature is influential in determining the number of nymphs produced, but it is evident that other factors such as humidity, evaporation, and sunshine are of direct importance.   It has been noted that a bright warm day, following a period of cool cloudy weather, would be accompanied by a considerable increase in the number of nymphs produced.   However, to determine the exact relation of environmental influence upon the rate of reproduction, will require further study with observation of as many factors of the environment as possible.

Effects of Environment upon Longevity.

The environment had an important effect upon the length of life of the apple aphids.   Periods of cold, rainy weather in early spring destroys many of the young nymphs before they reach maturity.   On the other hand, unusually high temperatures during late summer, apparently hastened the metabolism of the insects excessively, shortening the lives of the individuals affected.   Individuals feeding upon very hard, mature foliage do not live as long after maturity as do those on more succulent foliage.

EFFECTS OF APHIDS UPON GROWTH OF APPLES.

The most serious injury resulting from aphid infestation is the destruction of fruits by the direct attack of these insects. The several species show important differences in their power of injury to the fruit and foliage. The Rosy Aphis is the chief offender. Its attack produces a marked and characteristic contortion of the tissues attacked. It has frequently been observed that a single stem mother is sufficient to produce the characteristic curling of an apple leaf upon which it is feeding. Frequency with which this species attacks the developing fruit clusters, and its marked toxicity to the tissues combine to make the Rosy Aphis a serious orchard pest.

The Green Aphis seems to be quite as capable as the preceding species in producing injury to the infested fruit clusters. However the Green Aphis tends to feed upon the more succulent tissues of the plant, and hence attacks the fruit clusters much less frequently than does the Rosy Aphis.

The Apple-Grain Aphis very frequently infests the fruit clusters, but it seems to lack toxicity, and its attacks produce little or no visible effect upon the foliage or fruit.

At Geneva, N. Y. (12, p. 41-59) during the summer of 1916 a careful study was made of the comparative effects of the three species upon the growth of the fruit. The greatest inhibition in growth occurred in fruits attacked by Rosy Aphis.

The apples infested by the Apple-Grain Aphis showed little reduction in size. The effects of the Green Aphis upon the infested fruits were quite similar to the injury produced by the Rosy Aphis. In measuring the apples it was found that early in the season, the axial diameters were greater than the transverse diameters. The latter increased more rapidly, however, and soon became greater than the axial diameters. In the uninfested series the two diameters were approximately equal on June 30, whereas the infested series were equal about July 12. This indicates that the aphis attack inhibited the growth of the transverse diameter of the infested fruits to a greater extent than that of the axial diameter. This was found to be true in the case of each species, and varied directly with the severity of the injury produced.

SUMMARY.

Aphids are a group of insects of great biological interest and are among the most destructive of the orchard pests.

The species reported upon in this paper probably are world-wide in their distribution. They have infested apples in this country since the beginnings of our fruit growing industry.

All three species winter in the egg stage upon apple. The Green Apple Aphis spends the entire summer upon apple. The Apple-Grain Aphis spends the summer upon various grains and grasses. The Rosy Apple Aphis spends the summer upon plantain. The two latter species may continue to live upon their secondary food plants throughout the winter in mild climates. The three species pass through a seasonal succession that seems fundamentally constant in every section in which these studies have been conducted. These insects show variations in behavior as a result of climatic influences in different regions, which are of considerable significance from an economic standpoint.

Aphids seem unusually susceptible to the influence of environmental conditions. The number of generations produced during the season, the production of winged forms, and the production of gamogenetic forms, all seem to be regulated to a considerable extent by environmental conditions. An attempt has been made to illustrate, diagrammatically, the complex interrelations of the various factors of the environment. Detailed studies were made of the influence of evaporation and of temperature upon the development of *Aphis pomi*. It was found that evaporation, as registered by the instrument used, does not give a satisfactory index to the rate of development of this insect. When no other factor limits the development of the insect, temperature is a satisfactory index to the development of *Aphis pomi*, and the relationship may be expressed mathematically.

A study was made of the influence of age upon the rate of reproduction of *Aphis pomi*. This involved 128 adults, and covered a maximum reproductive period of 37 days. The average rate of reproduction for the first sixteen days was 3.23 nymphs per adult. After this time, the average rate of reproduction declined rapidly.

Studies of the effects of aphids upon the growth of apples showed an inhibition of the growth in direct proportion to the severity of the attack. The inhibition of the growth of the transverse diameter of the fruit was more pronounced than that of the axial dimension. The Rosy Apple Aphis produced the greatest effect upon the fruit, while the Green Aphis was scarcely less injurious. The Apple-Grain Aphid had comparatively little effect upon the growth of the infested fruit.

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ADDITIONS TO THE CATALOG OF OHIO VASCULAR PLANTS FOR 1927.*

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The past season has been unusually productive in bringing to light new plants as members of our flora. Several new genera and species have been added to the list and many new valuable records made of the geographic distribution of some of the species with limited ranges. The names of the contributors are given for each record as usual.

1. *Ophioglossum vulgatum* L. Adder-tongue. The form known as *O. engelmanni* Prantl, with a prominent, cuspidate leaf tip. This character intergrades with the rounded tip character and is, therefore, not regarded as of specific rank. Collected in prairie patches at Beaver Pond, Adams Co., by E. Lucy Braun.

19.1. *Lorinseria areolata* (L.) Presl. Net-veined Chain-fern. Lake Co. H. C. Beardslee.

51.1. *Equisetum nelsoni* (Eat.) Schaffn. Nelson's Scouring-rush "Along railroad." West of Holland. Lucas Co. E. L. Moseley.

52. *Equisetum laevigatum* R. Br. Smooth Scouring-rush. "On sand in corn-field" south of Bozart, Perkins Twp., Erie Co. R. B. Gordon. East of Fremont Sandusky Co. R. H. Moore.

53.1. *Equisetum kansanum* Schaffn. Kansas Scouring-rush. Near Sylvania, Lucas Co. R. B. Gordon.

60. *Lycopodium inundatum* L. Bog Club-moss. "In a sandy swamp." Millwood, Knox Co. C. H. Kennedy.

63. *Lycopodium complanatum* L. Trailing Club-moss. Hubbard Twp. Trumbull Co. Charles F. Walker. Ira, Summit Co. E. Cranz. Pine Grove, near Colbertson, Lawrence Co. Collected by B. E. Leete, Conrad Roth. Cutler, Washington Co. Amos Burgess. Ward Twp., Hocking Co.. Len Stephenson.

68. *Pinus strobus* L. White Pine. Ross Twp., Jefferson Co. T. Scott Sutton.

69. *Pinus rigida* Mill. Pitch Pine, Brush Creek Twp., Jefferson Co. Also in Saline and Ross Twps., Jefferson Co. T. Scott Sutton.

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236. *Carex platyphylla* Carey. Broadleaf Sedge. Nile Twp., Scioto Co. Also in Green Twp., Adams Co.. Conrad Roth.

246. *Carex oligocarpa* Schk. Few-fruited Sedge. Scioto River. N. W. of Columbus, Franklin Co. R. B. Gordon.

280. *Carex vesicaria* L. Inflated Sedge. Wabash railroad. Washington Twp., Henry Co. E. L. Moseley.

295.1. *Arundinaria tecta* (Walt.) Muhl. Small Cane. Brush Creek Twp., Highland Co. Katie M. Roads. Also found on the Old Shaker Farm (now the Otterbein Home) near Lebanon, Warren Co., by F. A. McClure.

328. *Poa autumnalis* Muhl. Flexuous Spear-grass. Along Turkey Creek near Portsmouth, Scioto Co. Conrad Roth. Ira, Summit Co. James H. Hine.

340. *Eragrostis capillaris* (L.) Nees. Capillary Love-grass. Hillsboro, Highland Co., also Mifflin Twp., Pike Co., Katie M. Roads.

352. *Arrhenatherum elatius* (L.) Beauv. Oat-grass. "Wayside near Maumee River, 2 miles above Volmer Park." Wood Co. E. L. Moseley.

372. *Hordeum vulgare* L. Common Barley. Penn Twp., and also Hillsboro, Highland Co. Katie M. Roads.

375. *Hordeum jubatum* L. Squirrel-tail Bailey. Buchtel, Athens Co. Len Stephenson.

396. *Alopecurus geniculatus* L. Marsh Foxtail. Buchtel, Athens Co. Len Stephenson.

417. *Anthoxanthum odoratum* L. Sweet Vernal-grass. Sandy Springs, Adams Co. Conrad Roth. Blanchester. Clinton Co. Katie M. Roads.

448a. *Panicum boscii molle* (Vas.) Hitch & Ch. New Vienna, Clinton Co. Katies M. Roads.

464. *Zinzania aquatica* L. Wild Rice. Estuary of Ottawa River, north of Toledo, Lucas Co. G. B. Sleesman & R. B. Gordon.

468.1. *Erianthus divaricatus* (L.) Hitch. Long-haired Wool-grass. Along Turkey Creek, Scioto Co. Conrad Roth.

470. *Andropogon virginicus* L. Virginia Beard-grass. Along road from Buchanan to Bainbridge. Ross Co. Katie M. Roads.

478. *Lilium umbellatum* Pursh. Western Red Lilly. Adams Co. In E. Lucy Braun Herb. E. Lucy Braun.

483. *Allium vineale* L. Field Garlic. "Pasture field" near Hillsboro, Highland Co. Katie M. Roads.

489. *Muscari botrydioides* (L.) Mill. Grape-hyacinth. Escaped near Briggsdale, Franklin Co. Robert B. Gordon.

490. *Aletris farinosa* L. Colic-root. "A fine colony along the road just outside of entrance to Boys Industrial School." Fairfield Co. Arthur R. Harper.

499. *Stenanthium robustum* Wats. Stout Stenanthium. South Webster, Scioto Co. Conrad Roth.

504. *Trillium declinatum* (Gr.) Gleason. Drooping Trillium. Maroon-flower variety. "Very abundant." Ward Twp., Hocking Co. Len Stephenson.

506.   *Trillium nivale* Ridd.   Early Trillium.   Near Yellow Springs, Clifton George, Green Co.   Miles L. Peele.   Concord Twp., Delaware Co.   Mrs. R. L. Gordon.

541.   *Juncus aristulatus* Mx.   Small-headed Grass-leaf Rush.   "Top of hill opposite Old Man's Cave," Hocking Co.   A. E. Waller.

557.3   *Iris foliosa* Mack. & Bush.   Leafy Blue-flag.   "On flood plain of creek.   Also naturalized in a garden near the patch from which this specimen was collected."   Near Glenmary, Franklin Co.   A. E. Waller.   St. Mary's, Auglaize Co. Collected by A. Wetzstein.

563.1   *Dioscorea bulbifera* L.   Air Potato (Yam).   "A very large patch along the road."   Hillsboro, Highland Co.   Katie M. Roads.

572.   *Limnorchis hyperborea* (L.) Rydb.   Tall Bog-orchis.   Brown's Lake Bog, Wayne Co.   E. S. Thomas and C. F. Walker.

573.   *Lysias orbiculata* (Pursh) Rydb.   Large Roundleaf Orchis. Hubbard Twp., Trumbull Co.   Charles F. Walker.

575.   *Blephariglottis ciliaris* (L.) Rydb.   Yellow Fringe-orchis.   Near Henley, Scioto Co.   Also head of Churn Creek, Adams Co. Arthur R. Harper.   Roosevelt Game Preserve, Scioto Co. Conrad Roth.   Sylvania, Lucas Co.   R. B. Gordon.

587.   *Ibidium plantagineum* (Raf.) House.   Wide-leaf Ladies-tresses. "Wet Soil along stream."   Beaver Pond, Adams Co.   E. Lucy Braun.

590.   *Ibidium praecox* (Walt.) House.   Grass-leaf Lady's-tresses. "In meadows."   Beaver Pond, Adams Co.   E. Lucy Braun.

593.   *Peramium pubescens* (Willd.) MacM.   Downy Rattlesnake-plantain.   "Moist ravine benches."   Big Walnut Creek, Westerville, Franklin Co.   W. H. Camp.

602.1.   *Hexalectris spicata* (Nutt.) Barnh.   Crested Coral-root.   "In mixed deciduous forest."   Jefferson Twp., Adams Co. E. Lucy Braun.

620.   *Ranunculus delphinifolius* Torr.   Water-crowfoot.   Westerville, Franklin Co., W. H. Camp.

632.   *Delphinium exaltatum* Ait.   Tall Larkspur.   Near Steam Furnace, Adams Co.   A. R. Harper.

664.   *Drosera intermedia* Hayne.   Spatulate Sundew.   "In a dry ditch two miles west of Whitehouse," Lucas Co.   E. L. Mosley.

665.   *Papaver somniferum* L.   Opium Poppy.   "In a vacant lot." Hillsboro, Highland Co.   Katie M. Roads.

667.   *Papaver dubium* L.   Corn Poppy.   North of Wakefield, Pike Co.   Arthur R. Harper.

688.   *Camelina microcarpa* Andrz.   Small-fruited False-flax.   Wapakoneta, Auglaize Co.   Wm. Kayser.

703.   *Thlapsi arvense* L.   Field Penny-cress.   "Waste field."   Liberty Twp., Highland Co.   Katie M. Roads.

705.   *Alliaria alliaria* (L.) Britt.   Garlic Mustard.   Three and one-half miles southwest of Urbana.   Champaign Co.   Arthur R. Harper.

708. *Cheirinia cheiranthoides* (L.) Link. Worm-seed Mustard. Wapakoneta, Auglaize Co. Wm. Kayser.

714. *Coringia orientalis* (L.) Dum. Hare's-ear Mustard. New Vienna, Clinton Co. Katie M. Roads. Also Wapakoneta. Auglaize Co. Wm. Kayser. Eaton, Preble Co. Carl N. Gibboney.

715. *Hesperis matronalis* L. Dame's Rocket. "In an old field." Madison, Lake Co. Earl Dodge and Fred J. Tyler.

728. *Arabis lyrata* L. Lyre-leaf Rock-cress. "Rocky cliffs at Vrooman's Bridge," Perry, Lake Co. F. J. Tyler.

733. *Cardamine rotundifolia* Mx. Roundleaf Bitter-cress. "Growing in creeks." Perry, Lake Co. F. J. Tyler.

742.3. *Leavenworthia uniflora* (Mx.) Britt. Michaux's Leavenworthia. Green Brier district, Adams Co. Conrad Roth.

747. *Brassica campestris* L. Summer-rape. Hillsboro, Highland Co. Katie M. Roads.

777. *Linum sulcatum* Ridd. Grooved Flax. In prairie. Lynx, Adams Co. E. Lucy Braun. Serpent Mound, Adams Co. A. R. Harper.

800. *Tithymalus obtusatus* (Pursh) K. & G. Bluntleaf Spurge. Liberty Twp., Highland Co. Katie M. Roads.

814. *Callitriche austini* Engelm. Terrestrial Water-starwort. "Red Hills" near Harlem, Delaware Co. Robert B. Gordon and Floyd Chapman.

829. *Hibiscus moscheutos* L. Swamp Rose-mallow. Stage Pond, Pickaway Co. C. F. Walker.

843. *Hypericum boreale* (Britt.) Bickn. Northern St. John's-wort. Two miles west of Whitehouse, Lucas Co. E. L. Moseley.

846. *Hypericum majus* (Gr.) Britt. Large Canadian St. John's-wort. Spencer Twp., Lucas Co. E. L. Moseley.

847. *Hypericum canadense* L. Canadian St. John's-wort. "In a dry ditch" two miles west of Whitehouse, Lucas Co. E. L. Moseley.

850. *Triadenum virginicum* (L.) Raf. Marsh St. John's-wort. Mud Lake, Holmes Co. E. S. Thomas and C. F. Walker.

855. *Lechea racemulosa* Mx. Oblong-fruited Pinweed. Buchtel, Athens Co. Len Stephenson.

866.1 *Viola walteri* House. Walter's Violet. "Prairie openings and arborvitae groves." Beaver Pond, Adams Co. E. Lucy Braun.

871. *Viola rotundifolia* Mx. Roundleaf Violet. Perry, Lake Co. F. J. Tyler.

878. *Viola sororia* Willd. Woolly Blue Violet. Abundant in ravines north of Columbus, Franklin Co. John H. Schaffner.

884. *Viola sagittata* Ait. Arrowleaf Violet. "Sandy loam east of Holland," Lucas Co. R. B. Gordon.

890.1. *Arenaria texana* (Rob.) Britt. Texas Sandwort. "Woods and prairie patches." Ellis Run, Adams Co. E. Lucy Braun.

908. *Lychnis alba* Mill. White Lychnis. "Abundant for 15 years at Perry," Lake Co. F. J. Tyler. Buchtel, Athens Co. Len Stephenson.

912. *Silene latifolia* (Mill.) Britt. & Rend. Bladder Campion. Painesville Twp., Lake Co. H. C. Beardslee. Also Perry, Lake Co. "Becoming rather common." F. J. Tyler. Also Madison, Lake Co. Earl Dodge.

923. *Vaccaria vaccaria* (L.) Britt. Cowherb. Wapakoneta, Auglaize Co. Wm. Kayser.

925. *Dianthus armeria* L. Deptford Pink. Perry, Lake Co. F. J. Tyler.

939. *Scleranthus annuus* L. Knawel. "An abundant weed in fields on Robert West farm." Perry, Lake Co. F. J. Tyler.

960. *Blitum capitatum* L. Strawberry Blite. Thompson, Geauga Co. Earl Dodge.

980. *Tracaulon arifolium* (L.) Raf. Halberd-leaf Tear-thum. Clear Creek, Hocking Co. Also near Sugar Grove, Fairfield Co. E. S. Thomas.

1017. *Waldsteinia fragarioides* (Mx.) Tratt. Dry Strawberry, Geauga Co. F. J. Tyler.

1027. *Rubus strigosus* Mx. Wild Red Raspberry. Streetsborough, Portage Co. E. S. Thomas.

1029. *Rubus phoenicolasius* Max. Wineberry. Brush Creek Twp., Highland Co. Katie M. Roads.

1044.1. *Rosa centifolia muscosa* Ser. Moss Rose. "Along R. R. track, Hillsboro, and along the road, Newmarket Twp." Highland Co. Katie M. Roads.

1045. *Rosa setigera* Mx. Prairie Rose. Perry, Lake Co. F. J. Tyler.

1053.1. *Sorbus aucuparia* L. European Mountain-ash. "Many small trees along the side of the road." Montville, Geauga Co. Fred J. and Harriet B. Tyler.

1098. *Chamaecrista nictitans* (L.) Moench. Sensitive-pea. Red Hills, Delaware Co. R. B. Gordon and A. R. Harper.

1103. *Baptisia tinctoria* (L.) R. Br. Yellow Wild-indigo. "Turkey Creek Road near base of divide," Scioto Co. A. R. Harper.

1104. *Baptisia leucantha* T. & G. Large White Wild-indigo. Tymochtee Twp., Wyandot Co. H. C. Sampson and R. B. Gordon.

1113. *Trifolium procumbens* L. Low Hop Clover. Red Hills, Delaware Co. R. B. Gordon and A. R. Harper.

1118. *Trifolium reflexum* L. Buffalo Clover. Red Hills near Harlem, Delaware Co. Robert B. Gordon and Floyd Chapman.

1123.1. *Anthyllis vulneraria* L. Lady's-fingers. "In meadow." Perry Twp., Lake Co. From Europe. H. C. Beardslee.

1134.1. *Coronilla scorpioides* (L.) Koch. Scorpion Coronilla. "Accidental but persistent." Wapakoneta, Auglaize Co. Wm. Kayser.

1157. *Lespedeza virginica* (L.) Britt. Slender Bush-Clover. Red Hills, Delaware Co. R. B. Gordon and A. R. Harper.

1160.1. *Lespedeza striata* (Thunb.) H. & A. Japan Clover, Wheerlesburg, Scioto Co. H. E. Eswine. Hillsboro, Highland Co. Katie M. Roads.

1169. *Lathyrus venosus* Muhl. Veiny Pea. Tymochtee Twp., Wyandot Co. H. C. Sampson and R. B. Gordon.

1077.2. *Soja max* (L.) Piper. Soybean. "Persistent after cultivation." Penn. Twp., Highland Co. Katie M. Roads.

1181. *Sedum triphyllum* (Haw.) S. F. Gr. Live-forever. Near Buchanan, Pike Co., also New Market Twp., Highland Co. Katie M. Roads.

1183. *Sedum acre* L. Wall-pepper. Hillsboro, Highland Co. Katie M. Roads.

1191.1. *Heuchera villosa* Mx. Hairy Alum-root. "On limestone cliff," Green Twp., Adams Co. Conrad Roth.

1193. *Chrysosplenium americanum* Schw. Golden Saxifrage. Thompson's Ledge, Geauga Co. F. J. Tyler.

1194.1. *Didiplis diandra* (Nutt.) Wood. Water-purslane. "In damp places near Grand-River," Madison, Lake Co. F. J. Tyler. Although this is a sterile specimen its general character and its square stems and linear to linear-lanceolate leaves indicate that it is Didiplis and not a Callitriche. J. H. S.

1205. *Rhamnus alnifolia* L'Her. Alderleaf Buckthorn. Streetsborough, Portage Co. E. S. Thomas.

1206.1. *Rhamnus frangula* L. Black Buckthorn. "Growing in fence rows." Lane, Perry Twp., Lake Co. From Europe. H. C. Beardslee.

1221. *Nemopanthus mucronata* (L.) Trel. Mountain Holly. Streetsborough, Portage Co. E. S. Thomas.

1229.1. *Acer pennsylvanicum* L. Striped Maple. In hemlock gorge, south of Conneaut, near Kingsville, Ashtabula Co. R. B. Gordon. Also found by H. L. Madison on southern shore of Lake Erie, about eight miles east of Ashtabula.

1266. *Quercus prinoides* Willd. Scrub Chestnut Oak. Jefferson Twp., Adams Co. Conrad Roth.

1286. *Alnus incana* (L.) Willd. Hoary Alder. Streetsborough, Portage Co. R. W. Franks.

1295.1. *Myrica carolinensis* Mill. Small Wax-berry. "In tamarack bog near Streetsborough," Portage Co. E. S. Thomas, C. F. Walker, R. W. Franks, and E. Cranz.

1323. *Opuntia opuntia* (L.) Coult. Common Prickly-pear. "Probably an Escape but propagating." Belpre Twp., Washington Co. J. K. Dodge.

1327. *Ribes vulgare* Law. Red Currant. "Along the road." Hillsboro, Highland Co. Katie M. Roads.

1338. *Epilobium lineare* Muhl. Linear-leaf Willow-herb. "In Sphagnum bog." Richmond Twp., Huron Co. Charles F. Walker and E. S. Thomas.

1339. *Epilobium strictum* Muhl. Downy Willow-herb. Streetsborough, Portage Co. E. S. Thomas and R. W. Franks.

1357.1. *Cucurbita lagenaria* L. Bottle Gourd. "A large patch in a pasture lot." Hillsboro, Highland Co. Katie M. Roads.

1379. *Trientalis americana* (Pers.) Pursh. Starflower. Thompson's Ledge, Geauga Co. F. J. Tyler.

1380. *Anagallis arvensis* L. Scarlet Pimpernel. Wapakoneta, Auglaize Co. Wm. Kayser.

1392. *Hypopitys lanuginosa* (Mx.) Nutt. Hairy Pinesap. Head of Clear Creek, Adams Co. A. R. Harper. Near Sylvania, Lucas Co. R. B. Gordon.

1399. *Chamaedaphne calyculata.* (L.) Moench. Leatherleaf. Aurora Twp., Portage Co. E. S. Thomas.

1402. *Epigaea repens* L. Trailing Arbutus. Adams Co. In E. Lucy Braun Herb. E. Lucy Braun.

1403. *Gaultheria procumbens* L. Creeping Wintergreen. Adams Co. In E. Lucy Braun Herb. E. Lucy Braun.

1410. *Vaccinium atrococcum* (Gr.) Heller. Dark Blueberry. Spencer Twp., Lucas Co. E. L. Moseley.

1419. *Phlox glaberrima* L. Smooth Phlox. "Along Turkey Creek Road near base of divide," Scioto Co. A. R. Harper.

1428. *Ipomoea lacunosa* L. Small-flowered White Morning-glory. Churn Creek, Adams Co. Also "on gravel bars of Scioto River," Scioto Co. A. R. Harper.

1433.1. *Convolvulus repens* L. Trailing Bindweed. Red Hills near Harlem, Delaware Co. Robert R. Gordon and Floyd Chapman.

1466. *Gentiana puberula* Mx. Downy Gentian. Two miles west of Whitehouse, Lucas Co. E. L. Moseley.

1472. *Obolaria virginica* L. Pennywort. Shawnee Forest, Brush Creek Twp., Scioto Co. Conrad Roth and Robert B. Gordon.

1473. *Bartonia virginica* (L.) B. S. P. Yellow Bartonia. Brailey, Fulton Co. E. L. Moseley.

1474. *Menyanthes trifoliata* L. Buckbean. Long Lake, Ashland Co. E. S. Thomas and C. F. Walker.

1487. *Asclepias sullivantii* Engel. Sullivant's Milkweed. Johnson's Prairie, Madison Co. Also Port Clinton, Ottawa Co. E. S. Thomas, and J. C. Hambleton.

1502. *Physalodes physalodes* (L.) Britt. Apple-of-Peru. Bainbridge, Ross Co. Katie M. Roads.

1515. *Solanum rostratum* Dun. Buffalo-bur. Edon, Williams Co. P. F. Shoup.

1521.1. *Chelone obliqua* L. Red Turtle-head. Clear Creek, Hocking Co. Edward S. Thomas.

1560. *Otophylla auriculata* (Mx.) Small. Auricled Gerardia. Adams Co. In E. Lucy Braun Herb. E. Lucy Braun.

1568. *Chaenorrhinum minus* (L.) Lange. Lesser Toadflax. "Railway embankment." Painesville Twp., Lake Co. H. C. Beardslee. Wapakoneta, Auglaize Co. Wm. Kayser. "In cinders along R. R." Ada, Hardin Co. Raymond A. Dobbins.

1597. *Myosotis arvensis* (L.) Hill. Field Forget-me-not. Wapakoneta, Auglaize Co. Wm. Kayser.

1598. *Myosotis virginica* (L.) B. S. P. Virginia Foget-me-not. Wapakoneta, Auglaize Co. Wm. Kayser.

1613. *Verbena canadensis* (L.) Britt. Large-flowered Verbena. Near Buchanan, Pike Co. Katie M. Roads.

1615. *Isanthus brachiatus* (L.) B. S. P. False Pennyroyal. "In a pasture." Wapakoneta, Auglaize Co. Wm. Kayser. "Along road from Sinking Springs to Buchanan, Western part of Pike Co." Katie M. Roads.

1626. *Scutellaria pilosa* Mx. Hairy Skullcap. "In prairie openings." Beaver Pond, Adams Co. E. Lucy Braun.

1629. *Scutellaria saxatilis* Ridd. Rock Skullcap. Near Henley, Scioto Co. Arthur R. Harper.

1656. *Mentha alopecuroides* Hull. Woolly Mint. Mercer Co. Wm. Kayser.

1663. *Agastache scrophulariaefolia* (Willd.) Ktz. Figwort Giant-hyssop. Peebles-Wamsley Road, Adams Co. A. R. Harper. Adams Co. In E. Lucy Braun Herb. E. Lucy Braun.

1686.1. *Salvia pitcheri* Torr. Wild Blue Sage. Probably accidental from the west. Along road, Wapakoneta, Auglaize Co. Wm. Kayser. Propagating itself from planted specimens, Columbus, Franklin Co. John H. Schaffner.

1713.1. *Anethum graveolens* L. Dill. Persistent after cultivation. Buchtel, Athens Co. Len Stephenson.

1727. *Foeniculum foeniculum* (L.) Karst. Fennel. "Along the road near Buchanan, Pike Co." Katie M. Roads.

1730. *Hydrocotyle americana* L. American Marsh-pennywort. Leroy Twp., Lake Co. H. C. Beardslee and F. J. Tyler.

1743. *Cornus femina* Mill. Panicled Dogwood. Hillsboro, Highland Co. Katie M. Roads.

1760. *Diodia teres* Walt. Rough Buttonweed. Turkey Creek Divide and also near Minford, Scioto Co. Arthur R. Harper.

1766. *Galium mollugo* L. White Bedstraw. Kelley's Island, Erie Co. R. B. Gordon.

1776. *Viburnum pubescens* (Ait.) Pursh. Downy Arrow-wood. Ada, Hardin Co. George Sleesman.

1778. *Viburnum scabrellum* (T. & G.) Chapm. Roughleaf Arrow-wood. Morgan Twp., Scioto Co. Conrad Roth.

1785. *Viburnum alnifolium* Marsh. Hobblebush. "Growing in dense shade in ravines near Grand R.," Leroy Twp., Lake Co. F. J. Tyler.

1790. *Lonicera canadensis* Marsh. American Fly Honeysuckle. "Marshy woods" north of Saybrook, Ashtabula Co. F. J. Tyler.

1794. *Lonicera japonica* Thunb. Japanese Honeysuckle. Bainbridge, Ross Co. Katie M. Roads.

1802. *Diervilla diervilla* (L.) MacM. Bush-honeysuckle. "Banks of Grand River," Perry, Lake Co. F. J. Tyler.

1807. *Antennaria solitaria* Rydb. Single-headed Everlasting. "Oak woods." Beaver Pond, Adams Co. E. Lucy Braun.

1857. *Phaethusa helianthoides* (Mx.) Britt. Sunflower Crownbeard. "Marl bank on Sinking Springs-Marshall Road," Highland Co. Arthur R. Harper.

1868.   *Bidens discoidea* (T. & G.) Britt.   Small Beggar-ticks.   Livingston–Black Lick Woods, Violet Twp., Fairfield Co.   Edward S. Thomas.

1886.   *Helenium nudiflorum* Nutt.   Purple-headed Sneezeweed.   Scioto Co.   A. R. Harper.

1906.   *Solidago flexicaulis* L.   Zig-zag Goldenrod.   Cynthiana, Pike Co.   Katie M. Roads.

1912.   *Solidago rigidiuscula* (T. and G.) Port.   Slender Showy Goldenrod.   "Growing in an old field with Solidago nemoralis." Perry, Lake Co.   F. J. Tyler.

1922.   *Solidago rigida* L.   Stiff Goldenrod.   "In prairie associations." Adams Co.   A. R. Harper.

1934.   *Aster azureus* Lindl.   Azure Aster.   "On limestone."   Paint Creek, Ross Co.   E. N. Transeau and E. S. Thomas.

1938.   *Aster drummondii* Lindl.   Drummond's Aster.   Prairie, Wilson's Corners, Madison Co.   Edward S. Thomas.

1940.   *Aster undulatus* L.   Wavy-leaf Aster.   Roosevelt Preserve, Scioto Co.   Arthur R. Harper.   Clear Creek, Hocking Co.   E. S. Thomas.

1944.   *Aster oblongifolius* Nutt.   Aromatic Aster.   "Rocky places and washes in prairie; very abundant."   Lynx, Adams Co.   E. Lucy Braun.   "On hill west of Bushy Fork Valley," Adams Co., near Scioto Co. line."   A. R. Harper.

1952.   *Aster multiflorus* Ait.   Dense-flowered Aster.   Johnson's Prairie, Madison Co.   E. S. Thomas and J. C. Hambleton.

1978.   *Kuhnia eupatorioides* L.   False Boneset.   Jefferson Twp., Adams Co.   Conrad Roth.

1980.   *Lacinaria cylindracea* (Mx.) Ktz.   Cylindric Blazing-star.   "Dry prairie."   Buzzard's Roost, Adams Co.   E. Lucy Braun.

1988.   *Elephantopus carolinianus* Willd.   Carolina Elephant's-food.   Wheelersburg, Scioto Co.   H. E. Eswine.

1992.   *Anthemis tinctoria* L.   Yellow Dog-fennel.   Painesville Twp., Lake Co.   H. C. Beardslee.

1999.   *Matricaria matricarioides* (Lees.) Port.   Rayless Camomile.   Penn Twp., Highland Co.   Katie M. Roads.

2014.1.   *Senecio plattensis* Nutt.   Prairie Squaw-weed.   Beaver Pond, Adams Co.   In E. Lucy Braun Herb.   Reported last year as *S. pauperculus* Mx.   Remove this record from distribution of No. 2014.   This is another interesting prairie plant from Southern Ohio.   Identified by Dr. J. N. Greenman.

2016.   *Tussilago farfar* L.   Coltsfoot.   Ira, Summit Co.   James S. Hine.

2023.   *Cirsium virginianum* (L.) Mx.   Virginia Thistle.   Along Turkey Creek Road, Scioto Co.   A. R. Harper.

2028.1.   *Centaurea maculosa* Lam.   Spotted Star-thistle.   "Collected in N. E. Ohio."   C. J. Willard.

2029.1.   *Centaurea vochinensis* Bernh.   Tyrol Star-thistle.   Cantwell Cliffs, Hocking Co.   C. Horton.

2029.2.   *Centaurea nigra* L.   Black Star-thistle.   "In pasture field."   Liberty Twp., Highland Co.   Katie M. Roads.

2030.1. *Centaurea solstitialis* L. Barnaby's Star-thistle. "In alfalfa field sown with seed from Argentina, S. Am." Columbus, Franklin Co. C. J. Willard.

2035. *Hypochaeris radicata* L. Long-rooted Cat's-ear. Painesville, Lake Co. H. C. Beardslee.

2039. *Sonchus arvensis* L. Field Sow-thistle. West Toledo, Lucas Co. H. C. Sampson and R. B. Gordon.

2039.1. *Sonchus uliginosus* Bieb. Glandless Field Sow-thistle. Railway near Madison avenue crossing. Painesville, Lake Co. F. J. Tyler. This is a large-headed species without glandular bristles on the peduncles and involucre. Was reported last year as a variety of *Somchus arvensis* L. (No. 2039).

2046. *Lactuca sagittifolia* Ell. Arrowleaf Lettuce. Perry, Lake Co. F. J. Tyler.

2047. *Lactuca villosa* Jacq. Hairy-veined Blue Lettuce. Clarksville, Clinton Co. Katie M. Roads.

2062. *Hieracium pilosella* L. Mouse-ear Hawkweed. Painesville, Lake Co. H. C. Beardslee.

MALLOPHAGA FROM OHIO BIRDS.*

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INTRODUCTION.

The following paper comprises a study of the order Mallophaga, which includes the biting lice commonly found on birds and mammals, with special reference to a list of the species found on Ohio birds.

Most of the specimens were collected by myself during the past five years. Also many specimens were collected by M. B. Trautman, C. F. Walker, R. W. Franks, R. M. Geist, and D. G. Hall, whose assistance and encouragement is gratefully acknowledged. I also wish to acknowledge the splendid assistance given by Dr. H. E. Ewing of the United States National Museum.

This paper is a revision of a thesis prepared for the degree of Master of Science at Ohio State University in June 1926. The original work was carried out under the direction and with the assistance of Professor Herbert Osborn of Ohio State University.

METHODS OF COLLECTING.

Mallophaga are best collected from freshly killed or live birds. Since it is very difficult to capture birds alive it becomes necessary to shoot them. I have used a twelve gauge shotgun for large birds and a .410 shotgun for the smaller birds. Several different sizes of shot and loads were used for the various sizes of birds and for different conditions.

The most satisfactory method is to examine the birds for lice immediately after shooting.them. The lice are fairly visible to the unaided eye and may be easily picked from the feathers with a pair of small tweezers or forceps. The lice are put directly into a small vial of seventy per cent alcohol for killing and preserving.

If it is not convenient to examine the birds in the field they should be securely wrapped in paper until time is available for examination. They are best wrapped by using a double sheet

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of newspaper, placing the bird in one corner, then rolling it in the paper, securely folding in the ends of the paper, until several thicknesses are around the bird. The paper should be secured by a string or rubber band.

After the death of the host the parasites either attempt to leave the body, usually migrating slowly toward the head, or simply die on the body of the host. The death of those remaining on the host usually ensues in two or three days. I have observed the death of some in four or five hours, and on the other hand, have collected live parasites from a bird skin six or seven days old. The death of the parasites can hardly be caused by starvation, in view of their feeding habits, but rather must be attributed to the lack of animal heat to which they have been accustomed during the life of the host.

Only lice from one individual bird should be placed in each vial. I have found the one dram homeopathic vials to be the best size for handling and filing for future reference. A label with the name of the host, locality, date and name of collector should be placed both in and on the outside of each vial. By keeping lice from individual birds separate it is possible to ascertain to some degree the population on the host. It is always well to preserve a few immature lice with the adults, as well as a few eggs, if any are found. The vials are then filed in a suitable rack until time is available for mounting some of the specimens on glass microscope slides for identification.

It is often possible to obtain Mallophaga from dried skins or mounted birds where they are found dead under the feathers. These skins must be handled carefully to prevent breaking the feathers and consequently ruining the skins for museum purposes. The lice from dried skins may be softened by dropping them into hot water before placing them in seventy per cent alcohol for preserving. Host records on museum specimens may be erroneus owing to the interchange of Mallophaga between hosts placed in the same collecting bag or otherwise associated together. Consequently lice found near the tips of the feathers may have strayed from another host and should not be saved unless similar ones are found next to the skin of the host and can safely be assumed natural parasites of that host. Practically all of the specimens studied in the preparation of this paper were collected from freshly killed birds.

MOUNTING.

The Mallophaga may be kept in seventy per cent alcohol indefinitely. The alcohol modifies the specimens but little; their hard chitin prevents appreciable shrinking, and the colors are due chiefly to the amount of chitinization on different parts of the body, a coloration not affected by alcohol.

It is best to mount only a few of the lice from each host and to keep the remainder in alcohol for future reference. The final collection is preserved by mounting on glass microscope slides. I have found that mounting in Canada balsam after clearing in potassium hydroxide gives the best results.

One dram homeopathic vials are used as containers throughout the mounting process. Separate vials are used for the various liquids and the lice are transferred between vials by means of a small wire loop which holds the specimen in a drop of the liquid. This prevents injury to the soft specimens which might ensue if tweezers were used.

The lice are taken from seventy per cent alcohol and placed in several changes of water before being placed in fifteen per cent cold potassium hydroxide. They are kept in this liquid from ten to forty-eight hours, depending on the amount of clearing desired. The heavily chitinized specimens require the longer time to clear satisfactorily. From the potassium hydroxide the lice are placed in several changes of water for about twenty-four hours before being placed in thirty per cent alcohol. After twelve to twenty-four hours they are placed in ninety-five per cent alcohol for at least twenty-four hours. The Mallophaga may be left indefinitely in this liquid before continuing the process. Next the specimens are placed in absolute alcohol for three to six hours then in xylol for a similar length of time. They are taken from the xylol and mounted directly in a drop of rather thin Canada balsam in the center of microscope slides and covered with round (18 mm.) cover glasses. This entire mounting process will require practically a week and should not be shortened. The specimens must be kept covered by one of the various liquids throughout the process, and must not be exposed to the air.

Euparal or diaphane may be used as a mounting fluid by taking the specimens directly from the ninety-five per cent alcohol to the mounting fluid on the slides. Euparal eliminates several steps in the mounting procedure but the slides may not

be as permanent as those mounted in balsam. Some workers have used glycerine jelly as a mounting fluid. In the course of time this evaporates from beneath the cover glass and ruins the specimens for further study.

It is preferable to mount only one individual or a pair of lice on each slide. The specimens are mounted so the cover glass will be in the center of the slide, allowing a label to be placed on each side of the cover glass. On the label to the left I put the common and scientific name of the host, the locality, date and name of collector and the mounting fluid used. On the label to the right of the cover glass I put the name of the louse, the sex and the name of the person who identified the specimen.

LIFE HISTORY AND DISTRIBUTION ON THE HOST.

The entire life of the Mallophaga is spent on the body of the host. The eggs are glued singly to the feathers of the host, usually along the shaft of the feather. The Mallophaga have a gradual metamorphosis, the young lice resembling the adult in external appearance and differing only in size, shape and degree of chitinization. The young nymphs moult several times before reaching adult size. The length of life and rapidity of multiplication has not been determined accurately for a single species of these insects since their habits make any such determination a matter of considerable difficulty. It seems evident from my observations as well as those of others that the winter is spent mostly in the egg stage on the body of the host.

The regions on the body of the host in which the different genera of Mallophaga are found are rather definite and have some significance attached to them. For instance a rapid running louse like *Menopon* or *Colpocephalum* will be found in the breast, anal or back regions. But such a slow one as *Philopterus* will be limited to the head or neck entirely. There are reasons for this distribution. The bird can not easily scratch off a heavy jawed and heavy clawed *Philopterus* from the neck region, nor will a limited amount of dusting do much good there. So also will a *Colpocephalum* escape if the bird attempts to catch it with the bill in a dorsal, anal or abdominal region. It escapes by running for which it is extraordinarily adapted.

Degeeriella is a fast running form found frequently in the breast region. *Esthiopterum* is a slim and fast genus found on

the feathers of the wing. *Trinoton*, very agile and strong of foot, infests the back and breast of most ducks. *Ricinus* infests the rump and back of many Passerine birds. It is therefore necessary that definite regions on the body of the host be examined and their distinct genera noted.

ECONOMIC IMPORTANCE AND ABUNDANCE.

Presence of lice on poultry causes great uneasiness, scratching and nervousness which result in loss of weight and a marked decrease in egg production. Among wild birds the effect is not so noticeable although the hosts certainly can not harbor these parasites without some discomfort. The injury is chiefly caused by the irritation of the skin of the host by the sharp-clawed feet of the parasites, rather than by any direct hurt through the feeding habits of the parasites. The hosts dust themselves frequently in an effort to smother out the lice. They also remove some from their body by picking with the bill and scratching with the feet.

The Mallophaga are purely ectoparasites (except one species which lives on the inside skin of the pelican's pouch) and live on the feathers and epidermal scales of the birds. Since they have biting mouthparts they can not suck blood, although they may feed on blood clots around wounds.

There are many species of Mallophaga which have been recorded from only one species of host while some species have been recorded from several closely related species of host. For example: *Philopterus subflavescens* is recorded from about fifty species of Passerine birds; *Degeeriella vulgata* is also common on many Passerines; *Philopterus melanocephalus* is common on terns while both *Philopterus gonothorax* and *Degeeriella ornata* are found on most gulls. Quite frequently several species of lice may occur on a single species of host: practically all wild ducks have the three species, *Trinoton querquedulæ*, *Esthiopterum crassicorne* and *Anatoecus dentatus;* the domestic chicken has six species quite commonly; the coot ten species; the bobwhite five species; etc. Certain genera of Mallophaga are found only on certain closely related birds as *Cuculoecus* on cuckoos, *Anatoecus* on ducks, *Ibidoecus* on ibises and *Dennyus* on swifts. These rather definite host relationships may be used to roughly determine the specimens of Mallophaga in many cases.

There seems to be two chief ways in which this peculiar distribution of parasitism may have come about. In the case

of genera of wide distribution such as *Philopterus, Degeeriella* and *Colpocephalum* it is entirely reasonable to suppose that the insects have been transferred from one host to another in comparatively recent times, that is since the differentiation on the present host forms. In other cases there may have been a differentiation of the insect along with the host form. This idea seems to have some support in the occurrence of markedly differing species exclusively on different species of host. Owing to their uniformity of food and habit and the absence of any apparently marked struggle for existence, the stimulus to a rapid differentiation among Mallophaga is wanting.

Mallophaga are found rather abundantly on birds which nest in colonies or which are otherwise closely associated. Migration of parasites probably occurs only when the bodies of the hosts come into contact. Kellogg states that on such a likely place as an ocean rock from which he had just scared away hundreds of perching sea birds, no Mallophaga could be found.

All water and shore birds seem to be rather heavily infested with Mallophaga. The lice which infest swimming and diving birds are not furnished with special contrivances for their pseudo-aquatic life. They never come, necessarily, into contact with the water since they live at the base of the feathers where the water never penetrates, and where they have a constant and sufficient supply of air for the longest submergence possible to the host. Hawks, owls, crows and other large land birds are usually infested while the smaller land birds are much less commonly infested, except those gregarious ones.

Some cases of straggling may be found in nature. Birds of prey may be found with lice which have undoubtedly come from some of their victims. Kellogg reports several cases where Mallophaga typical of water birds were found on land birds on small oceanic islands. This may be explained by the fact that land and water birds are frequently observed perching close together on the rocks so it would be very easy for some migration of parasites to occur.

CLASSIFICATION OF THE ORDER MALLOPHAGA.

The order Mallophaga includes the biting lice infesting birds and mammals. They are small, wingless, flat-bodied, active insects ranging in size from about 0.5 mm. to about 10 mm. They are entirely adapted for an ectoparasitic mode of

life and feed on the hair, feathers and epidermal scales of their hosts. Kellogg divides the order into two suborders as follows:

Suborder Amblycera—with clavate or capitate four segmented concealed antennæ; with four segmented maxillary palpi; mandibles horizontal.

Suborder Ischnocera—with filiform three or five segmented exposed antennæ; no maxillary palpi; mandibles vertical.

Harrison divides the Amblycera into six families: Boopidæ, Trimenoponidæ, Gyropidæ, Menoponidæ, Læmobothriidæ and Ricinidæ. He divides the Ischnocera into three families: Trichodectidæ, Nesiotinidæ and Philopteridæ.

The classification will not be discussed further in this paper since the works of Kellogg and Harrison may easily be consulted. In this list I follow the sequence used in Harrison's list so far as possible.

There are about 1700 described species falling in some 70 genera of Mallophaga in the world. In this list I have recorded 94 species of Mallophaga in 24 genera from 114 species of birds, all collected in the state of Ohio and practically all in my personal collection.

LIST OF MALLOPHAGA FROM OHIO BIRDS.

Order MALLOPHAGA Nitzsch.

Suborder AMBLYCERA Kellogg.

Family *Menoponidae* Mjoberg.

MENOPON Nitzsch.

M. FULVOMACULATUM Denny. Ring-neck pheasant, Columbus.
M. GALLINÆ (Linn.). Chicken, all parts of Ohio.
M. LOOMISII Kellogg. Mallard, *Anas platyrhyncha* Linn., Columbus.

EOMENACANTHUS Uchida.

E. STRAMINEUM (Nitzsch). Chicken, all parts of Ohio.

COLPOCEPHALUM Nitzsch.

C. FLAVESCENS Nitzsch. Bald eagle, *Haliætus leucocephalus leucocephalus* (Linn.), Columbus and New Bremen.
C. LATICEPS Kellogg. Black-crowned night heron, *Nycticorax nycticorax nævius* (Boddært), Buckeye Lake; great blue heron, *Ardea herodias herodias* Linn., Columbus and Fredericktown; little blue heron, *Florida cærulea* (Linn.), Columbus.
C. SUBPACHYGASTER Piaget. Barn owl, *Tyto alba pratincola* (Bonaparte), Fredericktown.

MENACANTHUS Neumann.

M. CHRYSOPHÆUM (Kellogg). Brown thrasher, *Toxostoma rufum* (Linn.), Buckeye Lake; meadowlark, *Sturnella magna magna* (Linn.), Sandusky; Pipit, *Anthus rubescens* (Tunstall), Columbus.

MYRSIDEA Waterston.

M. AMERICANA (Kellogg). Crow, *Corvus brachyrhynchos brachyrhynchos* Brehm., Columbus and Lancaster.

M. CUCULARIS (Nitzsch). Starling, *Sturnus vulgaris* Linn., Columbus and New Bremen.

M. DISSIMILIS (Kellogg). Bank swallow, *Riparia riparia* (Linn.), Sandusky; purple martin, *Progne subis subis* (Linn.), Sandusky.

M. INCERTA (Kellogg). Catbird, *Dumetella carolinensis* (Linn.), Buckeye Lake; dickcissel, *Spiza americana* (Gmel.), Sandusky; fox sparrow, *Passerella iliaca iliaca* (Merr.), Columbus.

ACTORNITHOPHILUS Ferris.

A. AEGIALITIDIS (Durrant). Killdeer, *Oxyechus vociferus* (Linn.), Sandusky and Columbus.

A. AFFINE (Nitzsch). Spotted sandpiper, *Actitis macularia* (Linn.), Columbus.

A. FUNEBRE (Kellogg). · Bonapart gull, *Larus philadelphia* (Ord.), Buckeye Lake; herring gull, *Larus argentatus* Pont., Buckeye Lake; Sabine's gull, *Xema sabini* Sabine, Buckeye Lake.

A. PUSTULOSUS (Piaget). Pectoral sandpiper, *Pisobia maculata* (Vieill.), Sandusky and Buckeye Lake.

A. MINUS (Kell. & Chap.). Sanderling, *Crocethia alba* (Pallas), Buckeye Lake and Sandusky.

A. TIMIDUS (Kellogg). Black-bellied plover, *Squatarola squatarola cynosuræ* Thayer and Bangs, Sandusky; golden plover, *Pluvialis dominica dominica* (Muller), Buckeye Lake.

TETROPHTHALMUS Grosse.

T. INCOMPOSITUS (Kell. & Chap.). Double-crested cormorant, *Phalacrocorax auritus auritus* (Lesson), Buckeye Lake.

T. TITAN (Piaget). White pelican, *Pelecanus erythrorhynchos* Gmel., New Bremen.

DENNYUS Neumann.

D. DUBIUS (Kellogg). Chimneyswift, *Chætura pelagica* (Linn.), Columbus.

TRINOTON Nitzsch.

T. QUERQUEDULÆ (Linn.). Baldpate, *Mareca americana* (Gmel.), Columbus and New Bremen; blue goose, *Chen cærulescens* (Linn.), Franklin County; American merganser, *Mergus americanus* Cassin, Buckeye Lake; European widgeon, *Mareca penelope* (Linn.),

Columbus; gadwall, *Chaulelasmus streperus* (Linn.), Columbus; horned grebe, *Colymbus auritus* Linn., Buckeye Lake; lesser scaup, *Marila affinis* (Eyton), Buckeye Lake; mallard, *Anas platyrhyncha* Linn., Columbus; pintail, *Dafila acuta tzitzihoa* (Vieill.), Buckeye Lake; red-breasted merganser, *Mergus serrator* Linn., Buckeye Lake and Columbus; shoveller, *Spatula clypeata* (Linn.), New Bremen; white-winged scoter, *Oidemia deglandi deglandi* Bonapart, Buckeye Lake.

EUREUM Nitzsch.

E. CIMICOIDES Nitzsch.   Chimneyswift, *Chætura pelagica* (Linn.), Columbus.

PSEUDOMENOPON Mjoberg.

P. PACIFICUM (Kellogg). Coot, *Fulica americana* Gmel., Buckeye Lake; Florida gallinule, *Gallinula chloropus cachinnans* Bangs, Buckeye Lake; horned grebe, *Colymbus auritus* Linn., Buckeye Lake; pied-billed grebe, *Podilymbus podiceps* (Linn.), Columbus.

P. TRIDENS (Nitzsch). Sora rail, *Porzana carolina* (Linn.), Buckeye Lake.

Family *Laemobothriidae* Mjoberg.

LÆMOBOTHRION Nitzsch.

L. NIGRUM Burmeister. Coot, *Fulica americana* Gmel., Buckeye Lake; Florida gallinule, *Gallinula chloropus cachinnans* Bangs, Buckeye Lake.

Family *Ricinidae* Neumann.

RICINUS Degeer.

R. ANGULATUS (Kellogg). Fox sparrow, *Passerella iliaca iliaca* (Merr.), Columbus; kingbird, *Tyrannus tyrannus* (Linn.), Sandusky; red-eyed vireo, *Vireosylva olivacea* (Linn.), Buckeye Lake.

R. DIFFUSUS (Kellogg). Vesper sparrow, *Pooecetes gramineus gramineus* (Gmel.), Columbus and Sandusky.

R. MELOSPIZÆ (McGregor). Song sparrow, *Melospiza melodia melodia* (Wils.), Buckeye Lake.

R. PALLENS (Kellogg). Northern yellowthroat, *Geothlypis trichas brachidactyla* (Swainson), Buckeye Lake; Tennessee warbler, *Vermivora peregrina* (Wils.), Lancaster.

R. PALLIDUS (Kellogg). Slate-colored junco, *Junco hyemalis hyemalis* (Linn.), Columbus.

R. SUCINACEUS (Kellogg). Least flycatcher, *Empidonax minimus* Baird, Columbus; wood pewee, *Myiochanes virens* (Linn.), Sandusky.

Suborder ISCHNOCERA Kellogg.

Family *Philopteridae* Burmeister.

GONIODES Nitzsch.

G. MAMMILLATUS Rudow.   Bobwhite, *Colinus virginianus virginianus*
(Linn.), Columbus and Sandusky.

G. MELEAGRIDIS (Linn.). Domestic turkey, Columbus.

G. PAVONIS (Linn.). Peacock, Columbus.

G. ZENAIDURÆ McGregor.   Mourning dove, *Zenaidura macroura car-
olinensis* (Linn.), Sandusky.

GONIOCOTES Burmeister.

G. BIDENTATUS (Scopoli). Pigeon, Sandusky.

G. GIGAS Taschenberg. Domestic chicken, Columbus.

G. HOLOGASTER Nitzsch. Domestic chicken, Columbus.

LIPEURUS Nitzsch.

L. ABERRANS McGregor.   Bobwhite, *Colinus virginianus virginianus*
(Linn.), Columbus.

L. CAPONIS (Linn.). Domestic chicken, Columbus.

L. DISSIMILIS Piaget. Bobwhite, *Colinus virginianus virginianus* (Linn.),
Columbus.

L. HETEROGRAPHUS Nitzsch. Domestic chicken, Columbus.

PHILOPTERUS Nitzsch.

P. AGELII (Osborn).   Red-winged blackbird, *Agelaius phœniceus phœ-
niceus* (Linn.), Buckeye Lake and Columbus.

P. CORVI (Osborn). Crow, *Corvus brachyrhynchos brachyrhynchos* Brehm.,
all parts of Ohio.

P. CURSOR (Nitzsch).   Long-eared owl, *Asio wilsonianus* (Lesson),
Columbus; saw-whet owl, *Cryptoglaux acadica acadica* (Gmel.),
Fredericktown; screech owl, *Otus asio asio* (Linn.), Columbus;
short-eared owl, *Asio flammeus* (Pont.), Fredericktown.

P. DOMESTICUS (Kellogg).   Purple martin, *Progne subis subis* (Linn.),
Sandusky; tree swallow, *Iridoprocne bicolor* (Vieill.), Columbus.

P. EVAGENS (Kellogg).   Yellow-bellied sapsucker, *Sphyrapicus varius
varius* (Linn.), Columbus.

P. GONOTHORAX (Giebel).   Bonapart gull, *Larus philadelphia* (Ord.),
Buckeye Lake; herring gull, *Larus argentatus* Pont., Columbus and
Lakewood; ring-billed gull, *Larus delawarensis* Ord., Buckeye
Lake.

P. JUGANS (Kellogg).   Flicker, *Colaptes auratus luteus* Bangs, Buckeye
Lake; red-headed woodpecker, *Melanerpes erythrocephalus* (Linn.),
Sandusky.

P. MAJOR (Waterston). Wilson's snipe, *Gallinago delicata* (Ord.), Buckeye Lake and Columbus.

P. MELANOCEPHALUS (Nitzsch). Black tern, *Chlidonias nigra surinamensis* (Gmel.), Sandusky; caspian tern, *Sterna caspia imperator* (Coues), Sandusky; common tern, *Sterna hirundo* Linn., Buckeye Lake and Sandusky; Forster's tern, *Sterna forsteri* Nuttall, Buckeye Lake.

P. MIRINOTATUS (Kell. & Chap.). Long-billed marsh wren, *Telmatodytes palustris palustris* (Wils.), Buckeye Lake.

P. PERTUSUS (Nitzsch). Coot, *Fulica americana* Gmel., Buckeye Lake; Florida gallinule, *Gallinula chloropus cachinnans* Bangs, Buckeye Lake; horned grebe, *Colymbus auritus* Linn., Buckeye Lake.

P. QUISCALI (Osborn). Bronzed grackle, *Quiscalus quiscula æneus* Ridgway, Buckeye Lake.

P. ROSTRATUS (Nitzsch). Barn owl, *Tyto alba pratincola* (Bonaparte), Buckeye Lake.

P. SIALII (Osborn). Bluebird, *Sialia sialis sialis* (Linn.), Columbus.

P. SUBFLAVESCENS (Geoffroy). Brown thrasher, *Toxostoma rufum* (Linn.), Sandusky; cardinal, *Cardinalis cardinalis* (Linn.), Groveport; field sparrow, *Spizella pusilla pusilla* (Wils.), Columbus; fox sparrow, *Passerella iliaca iliaca* (Merr.), Columbus; indigo bunting, *Passerina cyanea* (Linn.), Columbus; kingbird, *Tyrannus tyrannus* (Linn.), Sandusky; prairie horned lark, *Otocoris alpestris praticola* Henshaw, Columbus; robin, *Planesticus migratorius migratorius* (Linn.), Columbus; scarlet tanager, *Piranga erythromelas* (Vieill.), Buckeye Lake; slate-colored junco, *Junco hyemalis hyemalis* (Linn.) Columbus; swamp sparrow, *Melospiza georgiana* (Lath.), Buckeye Lake.

P. SYRNII (Packard). Barred owl, *Strix varia varia* Barton, Columbus.

P. TAUROCEPHALUS (Kellogg). Red-tailed hawk, *Buteo borealis borealis* (Gmel.), Tiffin.

ANATŒCUS Cummings.

A. DENTATUS (Scopoli). Black duck, *Anas rubripes tristis* Brewster, Columbus; hooded merganser, *Lophodytes cucullatus* (Linn.), Columbus; lesser scaup, *Marila affinis* (Eyton), Indian Lake; mallard, *Anas platyrhyncha* Linn., Columbus and Danville; oldsquaw, *Clangula hyemalis* (Linn.), Buckeye Lake and Columbus; pectoral sandpiper, *Pisobia maculata* (Vieill.), Sandusky; pintail, *Dafila acuta tzitzihoa* (Vieill.), Buckeye Lake; red-breasted merganser, *Mergus serrator* Linn., Buckeye Lake; ruddy duck, *Erismatura jamaicensis* (Gmel.), Indian Lake; scaup, *Marila marila* (Linn.), New Bremen.

A. FERRUGINEUS (Giebel). Lesser scaup, *Marila affinis* (Eyton), Buckeye Lake.

CUCULŒCUS Ewing.

C. COCCYGI (Osborn). Yellow-billed cuckoo, *Coccyzus americanus americanus* (Linn.), Sandusky.

EUSTRIGIPHILUS Ewing.

E. BUBONIS (Osborn). Great horned owl, *Bubo virginianus virginianus* (Gmel.), Berea.

E. CEBLEBRACHYS (Nitzsch). Snowy owl, *Nyctea nyctea* (Linn.), Fredericktown.

DEGEERIELLA Neumann.

D. ACTOPHILA (Kell. & Chap.). Buff-breasted sandpiper, *Tryngites subruficollis* (Vieill.), Sandusky; least sandpiper, *Pisobia minutilla* (Vieill.), Sandusky; sanderling, *Crocethia alba* (Pallas), Sandusky; semi-palmated sandpiper, *Ereunetes pusillus* (Linn.), Sandusky.

D. AMERICANA (Kell. & Chap.). Horned grebe, *Colymbus auritus* Linn., Buckeye Lake.

D. BŒPHILA (Kellogg). Killdeer, *Oxyechus vociferus* (Linn.), Columbus and Sandusky.

D. COMPLEXIVA (Kell. & Chap.). Baird sandpiper, *Pisobia bairdi* (Coues), Sandusky; least sandpiper, *Pisobia minutilla* (Vieill.), Delaware County; pectoral sandpiper, *Pisobia maculata* (Vieill.), Sandusky; sanderling, *Crocethia alba* (Pallas), Sandusky; semi-palmated sandpiper, *Ereunetes pusillus* (Linn.), Buckeye Lake; stilt sandpiper, *Micropalma himantopus* (Bonaparte), Buckeye Lake.

D. EUPREPES (Kell. & Chap.). Ruddy turnstone, *Arenaria interpres morinella* (Linn.), Sandusky.

D. FUSCA (Nitzsch). Cooper hawk, *Accipiter cooperi* (Bonaparte), Columbus and New Bremen; red-shouldered hawk, *Buteo lineatus lineatus* (Gmel.), New Bremen.

D. GRACILIS (Nitzsch). Purple martin, *Progne subis subis* (Linn.), Sandusky.

D. INTERPOSITA (Kellogg). Gray-cheeked thrush, *Hylocichla aliciæ aliciæ* (Baird), Sandusky.

D. MARGINATULA Harrison. Flicker, *Colaptes aurates luteus* Bangs, Columbus.

D. NEBULOSA (Burmeister). Starling, *Sturnus vulgaris* Linn., Columbus, Lakewood and New Bremen.

D. NORMIFER (Grube). Parasitic jæger, *Stercorarius parasiticus* (Linn.), Sandusky.

D. OPACA (Kell. & Chap.). Semi-palmated plover, *Charadrius semipalmatus* Bonaparte, Sandusky.

D. ORARIA (Kellogg). Golden plover, *Pluvalis dominica dominica* (Muller), Sandusky.

D. ORNATA (Grube). Bonapart gull, *Larus philadelphia* (Ord.), Buckeye Lake; herring gull, *Larus argentatus* Pont., New Bremen; kittiwake, *Rissa tridactyla tridactyla* (Linn.), Ohio; ring-billed gull, *Larus delawarensis* Ord., Buckeye Lake; Sabine's gull, *Xema sabini* Sabine, Buckeye Lake.

D. PRÆSTANS (Kellogg). Black tern, *Chlidonias nigra surinamensis* (Gmel.), Sandusky; caspian tern, *Sterna caspia imperator* (Coues), Sandusky; common tern, *Sterna hirundo* Linn., Sandusky.

D. RAVA (Kellogg). Spotted sandpiper, *Actitis macularia* (Linn.), Sandusky.

D. ROTUNDATA (Osborn). Crow, *Corvus brachyrhynchos brachyrhynchos* Brehm., Buckeye Lake.

D. SIMPLEX (Kellogg). Catbird, *Dumetella carolinensis* (Linn.), Columbus.

D. VULGATA (Kellogg). Cardinal, *Cardinalis cardinalis* (Linn.), Columbus; robin, *Planesticus migratorius migratorius* (Linn.), Columbus, Lakewood and Sandusky.

RALLICOLA Johnston & Harrison.

R. BISETOSA (Piaget). Sora rail, *Porzana carolina* (Linn.), Buckeye Lake and Sandusky; Virginia rail, *Rallus virginianus* Linn., Buckeye Lake.

ORNITHOBIUS Denny.

O. GONIOPLEURUS Denny. Hutchin's goose, *Branta canadensis hutchinsi* (Richardson), Buckeye Lake.

ESTHIOPTERUM Harrison.

E. BOTAURI (Osborn). American bittern, *Botaurus lentiginosus* (Montagu), Buckeye Lake and Columbus; great blue heron, *Ardea herodias herodias* Linn., Delaware County.

E. COLUMBÆ (Linn.). Pigeon, Sandusky.

E. COMSTOCKI (Kell. & Chap.). Sora rail, *Porzana carolina* (Linn.), Buckeye Lake; Virginia rail, *Rallus virginianus* Linn., Buckeye Lake.

E. CRASSICORNE (Scopoli). Baldpate, *Mareca americana* (Gmel.), Ohio; black duck, *Anas rubripes tristis* Brewster, Columbus and Delaware County; blue-winged teal, *Querquedula discors* (Linn.), New Bremen; European widgeon, *Mareca penelope* (Linn.), Granville; gadwall, *Chaulelasmus streperus* (Linn.), Columbus; lesser scaup, *Marila affinis* (Eyton), New Bremen; mallard, *Anas platyrhyncha* Linn., Columbus and Danville; red-breasted merganser, *Mergus serrator* Linn., Buckeye Lake and Columbus; shoveller, *Spatula clypeata* (Linn.), Columbus; american merganser, *Mergus americanus* Cassin, Buckeye Lake.

E. INFUSCATUM (Osborn). Woodcock, *Rubicola minor* (Gmel.), Delaware County.

E. LINEATUM (McGregor). Bobwhite, *Colinus virginianus virginianus* (Linn.), Columbus and Sandusky.

E. LURIDUM (Nitzsch). Coot, *Fulica americana* Gmel., Buckeye Lake.

E. TOXOCERUM (Nitzsch). Double-crested cormorant, *Phalacrocorax auritus auritus* (Lesson), Buckeye Lake.

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THE COLORIMETRIC DETERMINATION OF TOTAL PHOSPHOROUS IN PLANT SOLUTIONS.*

R. W. GERDEL,†

INTRODUCTION.

A review of the literature reveals a number of methods for colorimetric determination of the phosphorous content of soil, blood and urine. The adaptation of these methods to plant analysis has been apparently neglected.

Gilbert (5) has used the coeruleo-molybdate method of Deniges (3) for the estimation of phosphates in plant extracts and has found this method fairly reliable. His determinations, however, involve only the quantity of phosphorous found in the expressed juice, and not the total quantity in the plant. Parker and Fudge, (6) have adapted the coeruleo-molybdate method of Deniges (3) to soils and soil extracts, they also have used the aminonaptholsulfonic acid (4) and hydroquinone methods (2). They claim these reagents may be used for plant analysis as well as for soil.

Since a reliable colorimetric method for total phosphorous in plant samples would hasten this determination materially, an attempt was made to adapt to the plant sample a colorimetric method which is commonly used for soils and biological material.

ANALYTICAL METHODS.

There are various reducing agents which give a more or less quantitative color value with ammonium-phospho-molybdate. Among these reducing agents are stannous chloride, aminonaphtholsulfonic acid, phenylhydrazine-hydrochloride and hydroquinone.

Previous experiments have cast some doubt upon the reliability of color development by the coeruleo-molybdate method due to a lack of stability, while phenylhydrazine-hydrochloride does not develop a color of sufficient intensity. Either the aminonaphtholsulfonic acid reagent or hydroquinone seemed to offer the best possibilities.

Fiske and Subbarow, (4) outline the aminonaphtholsulfonic acid method as used for the determination of phosphorous in biological material. Arrhenius, (1) and Bell and Doisy, (2) have adapted the hydroquinone method to soils and biological material, respectively. These methods, by sufficient modification were adapted to plant solutions.

PREPARATION OF PLANT SOLUTION.

One gram samples of finely ground corn plants, dried at 65° C, were digested by the usual sulfuric-nitric acid wet digestion method. The clear solutions were filtered into 250 cc. volumetric flasks to remove dehydrated silica and made up to volume. Duplicate 50 cc. aliquots were used for the usual ammonium-molybdate volumetric determination.

TABLE I.

SAMPLE No.	MILLIGRAMS PHOSPHOROUS			NO₃
	Volumetric	Colorimetric		
		Salt Std.	Sample Std.	
1	.296	.194	Standard	—
2	.286	.235	.384	—
3	.354	.401	.371	+ +
4	.360	.369	.392	±
5	.323	.408	.254	±
6	.283	.333	.263	—
7	.313	.276	.255	+ +

AMINONAPHTHOLSULFONIC ACID METHOD.

A 25 cc. aliquot of the plant solution was tranferred to a 100 cc. volumetric flask and enough water added to bring the total to about 70 cc. The reagents of Fiske and Subbarow (4) were now added. These consist of 10 cc. of 2.5% ammonium molybdate and 4 cc. of 0.25% aminonaphtholsulfonic acid. The flasks were gently shaken and permitted to stand five minutes after which they were made up to volume and compared against a standard in the colorimeter.

The comparative values for phosphorous as determined volumetricaly and colorimetricaly are presented in Table I. In the first column of colorimetric values, the determinations were made against a standard consisting of a pure salt made up to contain 0.4 mgm. of phosphorous in 100 cc. Since the

results were so varied, the solutions were compared against one of the samples as a standard and the results are shown in the second column of colorimetric determinations.

Since the colorimetric values as determined by the comparison with a pure salt standard were rather inconsistent, it was thought that this might be due to an excess of sulfuric acid or traces of nitric acid in the wet digested plant solution. All of the samples have had approximately the same quantity of sulfuric acid added in the wet digestion process so one sample was selected as a standard. The use of a plant solution of known phosphorous quantity as a standard did not overcome the divergence between the volumetric and colorimetric values for phosphorous found in the same solution.

TABLE II.

| SAMPLE No. | MILLIGRAMS PHOSPHOROUS | |
	Volumetric Double ppt.	Colorimetric Single ppt.
8	.199	.301
9	.199	.326
10	.285	.727
11	.341	.301
12	.330	.260
13	.374	.430

A diphenylamine test was made on the solutions for the traces of nitrate which might remain after wet digestion. From the data in Table I it is apparent that this is not the factor which inhibits full development of color. However, it is advisable to heat the plant solutions for sufficient time after clearing to drive off the last traces of nitric acid used in the wet digestion process. Fiske and Subbarow (4) report that nitrates will interfere with color development when analyzing for phosphorous in biological material.

As a further check on the value of aminonaphtholsulfonic acid as the reducing agent, a series of duplicate precipitations were made by the usual ammonium-molybdate method. One duplicate was redissolved after the first precipitation and the phosphate determined colorimetricaly, the other duplicate was double precipitated and the phosphate determined titrametricaly. The color development by aminonaphtholsulfonic acid is hardly proportional to the actual quantity of phosphorous present as indicated in Table II. This may be due to the

presence of ammonia used in dissolving the precipitate before adding the color producing reagents.

To determine the stability of the color produced by aminon-aphtholsulfonic acid, readings were made at definite intervals over an hour and a quarter. Apparently the color was quite stable as shown in Table III.

Parker and Fudge (6), evaporated the soil solutions with 1 cc. N–1 Mg (No₃)₂ and ignited the residue. They found that there was practicaly no loss of phosphorous when they used this procedure. When $Mg(No_3)_2$ was not used they found a phosphorous loss of about 10% in some cases. This procedure as outlined by Parker and Fudge was tried with the plant solutions. The heat necessary to remove the sulfuric acid is sufficient to volatize the phosphorous compounds. In every case where

TABLE III

SAMPLE No.	MILLIGRAMS PHOSPHOROUS				
	Volumetric	Colorimetric			
		5 min.	20 min.	35 min.	75 min.
14	.441	.408	.398	.404	.414
15	.395	.333	.314	.325	.325
16	.437	.322	.343	.334	.349

the sulfuric acid was evaporated off, the color development with aminonaphtholsulfonic acid was not of sufficient intensity to ecure readings in the colorimeter.

Aminonaphtholsulfonic acid does not appear to be a reliable reducing agent for the colorimetric determination of phosphorous in wet digested plant material. The wide divergence between the volumetric and colorimetric values found for phosphorous in Tables I and II demonstrates that the reagent is not adapted to this particular procedure.

HYDROQUINONE METHOD.

The method as outlined by Bell and Doisy (2) was substituted for the aminonaphtholsulfonic acid method in the determination of phosphorous colorimetricaly in the plant solution. The general procedure was the same as for the previous method, 25 cc. aliquots of the plant solution were used, 5 cc. of the molybdic acid reagent added and then 2 cc.

of the hydroquinone reagent. The solutions were permitted to stand about ten minutes, the sulfuric acid was then neutralized with the carbonate-sulfite solution and the color allowed to develop for about one hour.

As previously noted with the aminonaphtholsulfonic acid method, the color development was not as intense in the solution as when an equivalent quantity of pure phosphate salt was useρ for a standard. The procedure seems to be more reliable if one of the plant solutions is analyzed volumetricaly and used as a

TABLE IV.

SAMPLE No.	MILLIGRAMS PHOSPHOROUS				
	Volumetric	Colorimetric			
		S-19	S-23	S-27	S-31
17	.570	.556	....	....	....
18	.563	.552	....	....	....
19	.515	.515	....	....	....
20	.482	.507	....	.•...........	....
21	.465	.462	....	....	....
22	.424	.415	.432	....	....
23	.404	.389	.404	....	....
24	.387	.376	.375	....	....
25	.347	.369	.332	.405	....
26	.323	.344	.309	.338	....
27	.310	....	.300	.310	....
28	.283	....	....	.279	....
29	.269	....	....	.252	.252
30	.252	....	....	.244	.218
31	.212	....	....	.227	.212
32	.202	....	....	....	.208
33	.174	....	....	....	.182

standard. Four different plant solutions ranging at intervals of about 0.1 mgm. of phosphorous were used as standards in Table IV. This eliminated to some extent the error due to light absorption when the colorimeter prisms are at widely different depths of solution. The columns designated by "S-19," "S-23," etc. represent the number of the sample used for the standard. In each case the samples were not compared with the selected standard when the solution under observation became too weak or too strong for efficient use of the colorimeter.

Comparison of the data in Table IV with Tables I and II indicates that hydroquinone gives more reliable results than aminonaphtholsulfonic acid when used with wet digested plant

material. It is to be noted especially, that the accuracy of the colorimetric determination is fairly good within a range of 0.05 mgm. above or below the standard. However as the standard used becomes more dilute the error in reading the colorimeter becomes larger. Also the dilute solutions seem to retard full color development. The data indicate that several standards of varying concentrations must be used if the samples under observation cover a wide range in phosphorous content.

The superiority of hydroquinone over aminonaphtholsulfonic acid may be explained on the basis of acidity concentration. Deniges (3) and Parker and Fudge (6) have shown that the acidity of the solutions under observation must be controlled

TABLE V.

SAMPLE NO.	MILLIGRAMS PHOSPHOROUS		
	Volumetric	Colorimetric	
		1 hour	5 hours
34	.320	.266	.277
35	.320	.257	.264
36	.387	.331	.320
37	.482	.392	.389

if comparative results are desired. The plant solutions in this instance are made up with sulfuric acid and there may be slight variations in acidity between samples due to volatization of the acid during digestion. The aminonaphtholsulfonic acid method does not neutralize this excess acidity. In fact the development of color by this method is dependent upon the 10 N sulfuric acid in the reagents. The reagent acidity is constant, but the sample acidity as previously mentioned, may vary to some extent.

With the hydroquinone method, color development depends upon the neutralization of the sulfuric acid present in the reagent with the carbonate-sulfite mixture. At the time of neutralization of reagent acidity, the carbonate-sulfite mixture is added in sufficient quantity to neutralize the sample acidity. This overcomes the differences in acidity between samples and causes a more comparative color development.

The color development by hydroquinone is remarkably stable as it changes but slightly over a period of several hours. This is a valuable characteristic since it enables the investigator

to make a large number of determinations at once without the possibility of the color fading or intensifying during the time of analysis. The data in Table V show that after a period of five hours the color had not materialy changed in the solutions.

CONCLUSIONS.

Phosphorous may be determined with fair degree of accuracy in plant material by a colorimetric determination on the wet-digested dry sample. Hydroquinone is preferable as a reducing agent.

The color development is neither proportionaly nor geometricaly progressive. For this reason the error cannot be corrected for by means of a table or curve. It may be minimized by using several standards, preferably at about 0.1 mgm. intervals.

The presence of sulfuric acid and other chemical substances in the plant solution prevents accurate determination of the colorimetic phosphorous values when compared with a pure salt standard. The results more closely agree with the volumetric analysis when a plant solution of known phosphorous quantity is used as a standard.

This method should not be considered as a reliable substitute for the usual volumetric determination. In cases where the number of samples to be handled is very large and a number of rapid and fairly accurate determinations are desired, the method can be used with the assurance of at least comparative results.

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NOTES ON THE HABITS OF APHIOCHAETA ALETIÆ.

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A somewhat detailed account of observations on the habits and development of a member of the dipterous family Phoridæ may be pardoned in view of the impression given in the literature that little is known of the activities of these flies. In his study of corn insects in Ohio, Dr. C. R. Neiswander has in the past few years, found specimens of the spindle stalk-borer (*Achatodes zeæ* Harris), a noctuid, in corn stalks. In the season of 1927, he took it very commonly in elder. On June 24, Dr. Neiswander showed the writer some larvæ of a hymenopterous parasite issuing from the backs of this borer. Incidental to observations on this parasite during the rest of the summer, the writer found three other species of insects, two dipterous forms, and one other hymenopterous species attacking these caterpillars. To date, December 1927, only one adult insect has appeared from the accumulated parasite material. This has been indentified as *Aphiochaeta aletiæ* Comst. of the dipterous family Phoridæ,† and it is the remarkable habits of this species that constitutes the occasion for this paper.

SUMMARY OF THE LITERATURE ON PHORIDÆ.

In his paper on this family, Malloch (1) states "that very little is known about their larval habits". . . . ."Those that have been reared have been for the most part upon fungi, or upon dead decaying animal or vegetable matter. Some species have been reared from snails and a few from the bodies

of bees, ants, or beetles, but whether the whole of these species were true parasites or not is a matter for conjecture. Several species are myrmecophilous." Malloch then (pp. 412-413) gives a list of some species whose habits are more or less known.

A survey of the economic literature on Phoridæ as given in the Review of Applied Entomology, Series A and B since 1913 when Malloch's paper appeared, demonstrates even further variety in the family habits. Morris (2) reared *Hypocera incrassata* Mg. from nearly full grown larvæ of *Bibio marci* that were unhealthy or dead after two weeks in the laboratory. He regarded this as a case of parasitism "being the first definite record of an insect parasitic on Bibionid larvæ." Wildermuth (3) records *Aphiochaeta perdita* from the pupæ of the alfalfa cater- pillar (*Eurymus eurytheme*), and, inasmuch as the chrysalids were alive when collected, believes that "the flies could not be acting as scavengers, but must have been true parasites." *Aphiochaeta* sp. is listed by Snow (4) as a parasite of the cut- worm, *Euxoa auxiliaris* Grote. The larvæ "were first seen actively moving around in" two cutworms, and fifteen adults issued from one of these. Ainslie and Cartwright (5) working with the lotus borer (*Pyrausta penitalis* Grote), obtained *Aphiochaeta chaetoneura* Mall., but state that they "were undoubtedly scavengers" because sound larvæ or pupæ were not attacked, and they lived equally well on putrid vegetable matter." The larvæ of various lady-beetles (6) are attacked by *Aphiochaeta fasciata* Fall. in France. In Mexico, Nocedo (7) records *A. scalaris* Lw. as a newly found parasite of *Schistocerca peregrina*, while Oberstein (8) in Germany, found many larvæ of *Phora rufipes* Meig. attacking swollen seeds and young seedlings of Woll-Luzerne.

In the field of medical entomology are habits as follows: Roberg (9) obtained nine phorid species from decaying animal matter, none of which were *Aphiochaeta*. *Aphiochaeta fer- rugines* was found by him to be the commonest of flies breeding in human faeces, and evidence shows this species to be a possible carrier of Asiatic cholera and, by analogy, other alimentary infections. The same species (*A. Scalaris* Tw. = *A. fer- ruginea* Brunetti) develops in decaying meat according to Fletcher (10), and Spooner (11) found it in milk which suggested to him the possibility that this is the source of the larvæ which have caused myiasis of the human intestine. The same writer cites records of its occurrence on onions in the West Indies,

in decaying insects in Brazil, and as a parasite of *Hyphantria cunea* in Florida. Cases of cutaneous myiasis in man and animals, involving *A. xanthina* Speis. and *A. rufipes* Mg. in India, are described by Patton. This writer (13) later reports *A. xanthina* bred from dung of horses, cats and dogs, from stale and decaying meat, and from dead insects. The females will oviposit in sores.

The species of Phoridæ, and those of *Aphiochaeta* in particular, therefore have habits ranging from scavengers on plant and animal remains to true parasites on insects and higher animals. Most often, however, the object of attack gives evidence of decomposition in greater or lesser degree.

APHIOCHAETA SP. FROM THE SPINDLE STALK-BORER.

Among the spindle stalk-borers collected on June 25, the writer noticed one individual that bore fifty small eggs on the back of the abdomen. No others carrying eggs in this way were found. The eggs were two-fifths of a mm. long and one-third as thick, with ends broadly rounded, and the surface smooth and whitish (Fig. 2). The parent fly had no definite scheme of depositing the eggs, but scattered them about miscellaneously here and there, this way and that, some lying upon others in a criss-cross manner.

Among the jumble of eggs were noticed several minute maggots awkwardly making slow progress hither and thither. Some stood up attached to the borer by the blunt end of their abdomens and explored the surroundings. Some maggots were still present on the back of the borer on June 26 and 27, and others had died there. Some died before hatching, but most eggs were empty. By June 28, all live maggots had disappeared from the back of the caterpillar. Where did they go, and what were they doing in connection with the borer? They did not penetrate the body as parasites. The borer was alive, and scarcely seemed to be a subject for attack of scavenger maggots.

The answer was found on June 28, when, by careful scrutiny of the caterpillar and its burrow in the elder stem, six maggots were seen in a cluster writhing over one another in a mass at the posterior end of the caterpillar. They were not attached to the borer. Further inspection revealed four more maggots of the same kind, but larger, moving about actively in the rectum of the borer. In a short time, these had disappeared

further into the lumen of the alimentary tract of the *Achatodes*, and in all subsequent observations, the maggots proved to have a strong negative light response. The anus of the borer was already widely and permanently distended. During the next week, daily examination showed that their occupancy of the rectal chamber was the true habit of the maggots in this case, and futhermore, they not infrequently left this cavity and reentered it, by way of the anus at all times. The body wall of the caterpillar was not broken by them. Almost daily, one or more of the maggots were seen outside of the caterpillar, and several times individuals were caught in the act of entering their habitation; or, if not conveniently located to enter the borer when their cage was opened, they took refuge under the borer's body. When the *Achatodes* lies in its normal position the anal aperture is almost flat on the floor of the burrow in the elder stem, which provides leverage for the maggots and makes entrance very convenient. The maggots also move more or less over the outside of the body, supported by the irregular surfaces of the segments.

The presence of the larvæ in the hind third of the body caused this portion to bulge out noticeably whenever they were inside the caterpillar. Only four of the maggots reached maturity. Most of the fifty were never seen. The borer had a tunnel a foot or more long extending from one internode to another. If it was able to crawl when the first maggots attacked it, this would suggest that many maggots died of starvation.

Development of the Fly.

Hatching seemed to be distributed over several days, and the eggs may have been deposited at different times. The egg shells clung to the borer as long as the latter was observed. Some larvæ had gone from the eggs on June 25, and half grown larvæ were seen on June 27. On the 25th, small larvæ still crept over the caterpillar. Growth was rapid. The days were the hottest of the summer. The larva stage required at least eleven days and probably not more than fifteen days. All the four surviving maggots had transformed to puparia by July 6, and the first puparium was seen on July 2. Upon maturity, the larvæ left the body of the borer and somehow secured themselves to various levels of the burrow of the caterpillar. Only one adult developed from the puparia even though they were kept moist constantly. This fly issued during the day of

July 13, and required between seven and eleven days to transform. The adult is restless, very active, able to run rapidly and travels also by short flights, and by jumping.

FOOD OF THE APHIOCHAETA LARVÆ.

In view of the common occurrence of the larvæ of an internal hymenopterous parasite in the spindle stalk-borers in June, it was thought possible that the *Aphiochaeta* larvæ might be devouring the parasites. But such Hymenoptera were apparently lacking. The maggots had not entered the body further than the posterior third. This region was found to be empty, the proctodaeum had been entirely reduced to an unrecongizable state, and only small amounts of fat body adhered to the inner surface of the body wall. Anterior to this region, the contents of the body were undisturbed and normally white. This situation showed that not the faeces of the caterpillar, but its store of adipose tissue was the chief source of food of the *Aphiochaeta* larvæ.

RELATION OF APHIOCHAETA TO THE SPINDLE STALK-BORER.

The borer was almost or quite full-grown and flabbid, when first seen on June 25, and scarcely moved from its original position while it lived—a period of seven days after its discovery. The body showed indications of disease—the anterior third of the body, and the last three abdominal segments being darkened; and the flabbid condition also pointed to this state. Other larvæ of this size were found entirely blackened, weakened and killed by a disease at the same time. Hence, the borer was probably quite feeble when the first maggots hatched. However, inasmuch as the maggots that were first seen in the rectum were about half grown, the status of the borer at the time they made their initial entrance is not positively known. But the occurrence of the disease is not in doubt, and this caterpillar may not be regarded as a normal individual. Some degree of putrefaction or similar phenomenon would seem to have been the influence that attracted the parent *Aphiochaeta* to it for oviposition. If parasitism be defined as existence of one or more organisms at the expense of one other normal individual, then *Aphiochaeta* was, in the present instance, a high grade scavenger, and not a true parasite. Inasmuch as diseases of lepidopterous larvæ and pupæ are common, and

because their presence is often not indicated externally until they have reached an advanced stage of development, it is plausible that most, if not all, instances of attack by Phoridæ may be upon organisms more or less debilitated by internal disorders.

Aphiochaeta sp. may not be considered as obligated to *Achatodes zeæ*, although its ability to find a borer in a stem with few openings indicates a keen sense if not a regular habit. This caterpillar pupates in June and July in old stems of the previous year's growth, and no more larvæ occur till the next
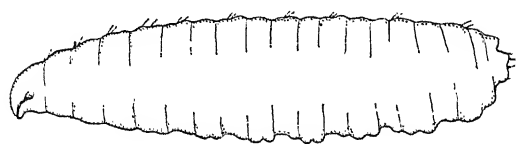
Fig. 1—19 X
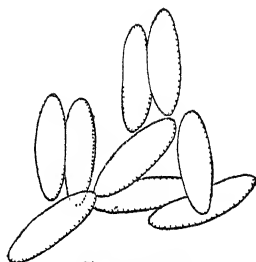
Fig. 2—32 X
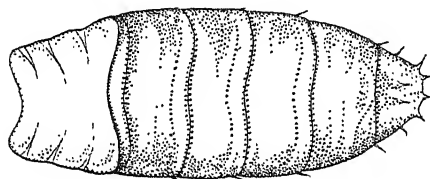
Fig. 3—24 X

year. But the occurrence of another generation of *Aphiochaeta* is indicated by the development of an adult. It may be that an earlier as well as a later generation arises in the excreta of the borers, upon decaying organic matter or upon insects of an entirely different sort. If so, entrance to a source of food by way of the anus is not habitual, although extremely unusual, and broadens our present conception of the eccentricity and diversity of habit in the family Phoridæ.

EMERGENCE OF THE ADULT: RELATIONSHIP.

In emerging, the adult removed entirely the terga of the first four segments, the sterna remaining intact and entire.

Hence, the aperture is not terminal, but dorso-terminal. Neither is it circular as in the calyptrate Diptera, but trapezoidal in shape. These features are not strictly cyclorrhaphous, but there is no suggestion of a straight or T-shaped seam, hence the relationship of the species is decidedly with the suborder Cyclorrhapha.

The adult (Fig. 4) is one and six-tenths mm. long, robust, with a prominent humped and somewhat spiny pronotum.

Fig. 4 - 32 X
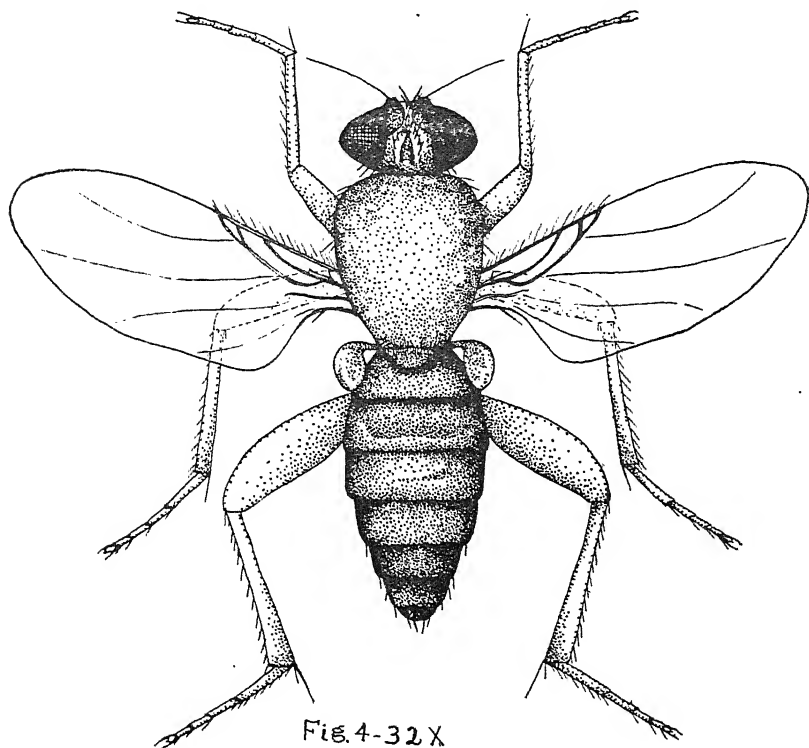
The angular black eyes stand out conspicuously. The antennæ are globular and one-segmented, with a long arista bearing short fine pubescence. The thorax is brown, the first and third segments much reduced above, and the halteres are large and scale-shaped. On the basal half of the front margin of the wings is a row of stout hairs, and the venation is reduced to three longitudinal veins and two basal ones, to the distal one of which the longitudinal veins are attached. The legs are amber-colored at base, with dusky tibiæ and tarsi, and all

the femora are flattened and enlarged for jumping, those of the hind legs being the largest. The abdomen is black, seven-segmented, tapers posteriorly, and is strongly depressed.

Description of The Larva.

The larva (Fig. 1) is of the muscoid type with sub-conical body. All were entirely white except one that had several fine transverse rings of black segmentally on the front end of the body. The rings persisted until the maggot was full grown. Newly hatched individuals measure 1.00 mm. long, and the largest were 3.10 mm. in length. Viewed from above, fifteen pairs of lateral, cuticular, sharp conical processes, or hairs, arranged segmentally, are visible. On the posterior end is a slightly heavier pair of similar construction that forms a curved transverse row with the lateral pair of the last segment. On each segment are also a pair of humeral and two pairs of dorsal processes, like the lateral pair in size and form. The median dorsal pair arises near the front edge of the segments, the lateral pairs are median on the pleuron, and the other four of each segment form a crooked line with the others. No such structures occur on the venter.

Each dorsal segment consists of three transverse areas. The first, which bears the median dorsal processes, is as long as the third, and the second is two-thirds the length of either of the other two. The first is slightly and more sharply convex than the third, and the middle one lies lower than either the first or third. Three low rounded fleshy elevations are present on the sterna. They are arranged in triangles by segments, the third member situated anterior to the pair. A fourth and similar hump is located in front of the anterior member of the triangle.

Descriptions of the Puparium and the Adult.

The puparium (Fig. 3) is rich, light brown, and about two one-fifth mm. long, and has a maximum width of one mm., both ends being noticeably narrowed. The venter is moderately convex, and the dorsum somewhat more rounded. A prominent humeral ridge, rounded above, extends from end to end on each side. To these are united similar transverse segmental ridges.

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THE CERIC ACID REACTION WITH PARTICULAR REFERENCE TO SUBERIN.*

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INTRODUCTION.

The ceric acid reaction of Doepping (1) as later modified and defined by von Höhnel (4), is recognized by chemists to be a valuable test for the presence of suberin or cutin in plant tissue. This is because of the fact that none of the other cell wall constituents of plants when treated with a strong oxidizing mixture such as nitric acid and potassium chlorate yield similar products of oxidation. We do not know, however, what ceric acid, or the product of this so called ceric acid reaction, really is. It might be thought of as a definite compound, or as a mixture of the fatty acids of which suberin and cutin are composed. Under the first supposition one would naturally infer that the suberized and cuticularized portions of cell walls are very similar in composition. This assumption, however, would be at variance with experimental evidence presented by van Wisselingh (7). The object of this investigation of the product of the ceric acid reaction of suberin is to determine if this product is simply a mixture of the fatty acids of which suberin is known to be composed, and to endeavor to isolate and identify these respective acids.

HISTORICAL.

The ceric acid reaction was first reported by Doepping (1) in 1843. He obtained a substance which he called cerine, from the bark of the cork oak, *Quercus suber*, by extracting with alcohol or ether. The substance was crystalline, soluble in potassium hydrate and, when treated with concentrated nitric acid, a yellow or golden-yellow, wax-like product was obtained, to which the name ceric acid or cork wax was given. Doepping did not believe that all of the cerine could be extracted with alcohol or ether, because of the fact that bark, after extraction,

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upon being treated with concentrated nitric acid, still yielded a substance similar in appearance and solubility reactions to ceric acid.

Von Höhnel (4), in 1877, modified the reaction by using nitric acid and potassium chlorate. He proposed this as a valuable test for the detection of both suberin and cutin, both substances yielding, when oxidized, oil-like globules which coalesced upon the surface of the liquid. He further characterized ceric acid as melting between 30° and 40°C. and soluble in boiling alcohol, ether, chloroform, benzol, and dilute potassium hydroxide. In von Höhnel's opinion there was no relation between cerine and ceric acid.

In his researches on the bark of the cork oak, Kügler (5) reported the presence of cerine, a higher alcohol, with a melting point of 250°F, stearic acid, phellonic acid, glycerine, and small quantities of coniferin and vanillin. The cork residue, after these substances had been extracted, did not yield ceric acid when oxidized. Van Wisselingh (7), using for the most part microchemical methods, detected both fusible and infusible substances present in the suberized walls of cork, and made special reference to phellonic acid. He considered suberin as a composite product of fatty acids or of analagous substances, such as ethers, glycerides, or compound ethers, and of one or more non-fusible substances, insoluble in chloroform, but which are decomposed by potassium hydroxide.

About the some time, Gilson (3), using the machrochemical methods of organic analysis, isolated three fatty acids, viz., phellonic, a white crystalline substance, melting at 95° to 96°C. suberic semi-liquid at ordinary temperatures and phloïonic crystallizing in white needles melting at 120° to 121°C. He also reported the presence of glycerine. In his investigations, the bark of the cork oak, *Quercus suber*, also of *Ulmus campestris*, var. suberosa, were used. In the latter, no phloïonic acid was found, and only a very small quantity in the former.

Gilson (3) considered suberin to be a mixture of compound ethers slightly fusible and insoluble in such solvents as alcohol, ether, and chloroform, or a product of combination, condensation, or polymerization of the acids or their derivatives. In this respect he was not in agreement with Kügler, who considered suberin to be a fat in the exact sense of the word.

After reviewing and confirming the work of Gilson, Priestly (6) states that we may consider suberin as an aggregate of

variously modified forms, possibly of condensation products or anhydrides of the acids present; also that the suberogenic acids are to a small extent combined with glycerine thus partaking of the nature of true fats.

In cutin, Fremy and Urbain (2) reported the presence of two fatty acids, stearocutic and oleocutic. All investigators agree that phellonic acid is lacking in cutin. On the other hand, van Wisselingh, in his summary of his researches on cutin and suberin, definitely states that there are no acids in suberin identical with the stearocutic and oleocutic of cutin. When both substances were heated in glycerin at 300°C. the residue from suberin is readily soluble in chromic acid while that from cutin is not. According to this author, both kinds of lamella yield ceric acid when oxidized with nitric acid and potassium chlorate. Cerine has never been mentioned as a constituent of cutin.

Since there appears to be a general agreement especially among the latter investigators that suberin and cutin are distinctly different substances, the question arises as to whether the ceric acid obtained in each case is the same compound, or varies according to its source.

EXPERIMENTAL.

When the cerine, which, according to Doepping (1) could be extracted from cork by hot alcohol or ether, was oxidized with nitric acid and potassium chlorate, the product obtained softened, but did not melt at the boiling temperature of water, whereas the product of oxidation of the cork residue, after the cerine was removed, or of the entire cork lamella, including the cerine, melted between 30° and 40°C. Evidently, similar observations led von Höhnel (4) to disregard cerine as the source of ceric acid. Since suberin and cutin are recognized to be aggregates of fatty acids, it seemed reasonable to assume that their products of oxidation may likewise be mixtures of the same fatty acids of which they are composed. The ceric acid obtained from the suberin of cork was investigated from this point of view.

The work of Gilson (3) was repeated, using a granulated cork, in order to gain familiarity with the details of analysis and also for the purpose of securing samples of the various acids for later comparison. The same method of analysis was

adapted as far as possible in the analysis of ceric acid produced from the ceric acid reaction.

The ceric acid was prepared by macerating granulated cork in a mixture of equal parts of a concentrated, aqueous solution of potassium chlorate and nitric acid specific gravity 1.42. The mixture was heated to boiling and the reaction allowed to continue until the cork was completely disintegrated and oxidation was complete. At this stage a layer of golden yellow wax-like substance fused together and spread over the surface of the liquid. After cooling upon ice it solidified and became brittle. The wax was then removed and washed with distilled water until no trace of nitrates remained; about 20 grams being prepared in this way. It was then dissolved in 250 cc. of boiling alcohol and filtered. Only the portion which was completely soluble in boiling alcohol was used in the analysis.

After filtering sufficient solid potassium, hydroxide was added to make a 3 percent solution and the acid was saponified by refluxing for one hour, care being taken to keep the solution distinctly alkaline to litmus paper. With the addition of the alkali, the color quickly changed, even with slight heating, from a straw yellow to dark brown. After refluxing and cooling upon ice a flocculent brownish white precipitate settled to the bottom of the flask. The precipitate was removed by filtering, washed with alcohol and recrystalized three times out of hot alcohol, by cooling. The alcohol was then removed by heating on a water bath. When some of the residue was then treated with a solution of iodine and potassium iodide and afterwards a few drops of 12 percent sulphuric acid or with chloro-zinc-iodide the typical rose or rose violet color indicative of potassium phellonate appeared.

The precipitate was further purified by boiling in a 25 percent solution of sodium chloride made alkaline with potassium hydroxide until the greater portion of the coloring matter was removed. It was then taken up in hot, distilled water and sulphuric acid added in excess to set free the acid from the potassium salt. After filtering, and washing to remove sulphates the residue was dried on a water bath; then recrystallized several times from alcohol, finally from chloroform, and allowed to stand in a desiccator over sulphuric acid for several days. The melting point was found to vary from 93° to 95°C. This is below the melting point of phellonic acid which is given as 95° to 96°C. When the residue was treated with chloro-zinc-

iodide particles were noticed which were yellow to yellowish brown in color, whereas the greater part of the preparation showed the rose or rose violet characteristic of phellonic acid and its salts, with the exception of the copper salt which colors brown. It was thought probable that this impurity was due to the fatty acid derived from the oxidation of the cerine. This acid appeared to be similar in solubility reactions to the phellonic and its potassium salt. It was very difficult to remove this impurity. After crystallizing again three times from hot alcohol, and the same number of times from boiling chloroform, a product was obtained which melted at 95°C. When a portion of this acid was thoroughly mixed with an equal quantity of known phellonic acid which had previously been extracted from cork, the melting point remained unchanged. The evidence appeared to be sufficient to conclude that phellonic acid had been isolated from the product of the ceric acid reaction.

The potassium salt of phellonic acid prepared from the acid gives the distinguishing rose or rose violet color with the iodine reagents, much better than the crude salt. This salt also gives the color reaction much more readily than the acid. When small particles showing the rose violet color were removed from the iodine solution and placed in a drop of water, the color promptly disappeared. It also disappeared from the iodine solution upon warming, and reappeared upon cooling.

The analysis was continued with the first filtrate following Gilson's (3) method and both suberic and phloïonic acids were isolated. These acids forming the product of the ceric acid reaction, appeared to be identical with those obtained from cork by the extraction method. Only a very small quantity of phloïonic acid was secured, not enough for confirmatory melting point determinations. The fine needles which crystallized out of hot water, upon cooling, could not be distinguished from those isolated from the cork extract. Less attention, however, has been directed to these acids because no tests have been discovered for their detection which would be adapted for microchemical use. It is for this reason that so much attention has been given to phellonic acid, more particularly to its potassium salt. The color which is given with the iodine reagents is so distinctive that it can be detected in very minute quantities; yet there is less than one fourth as much phellonic acid as suberic acid in the suberine of cork, according to Gilson (3).

SUMMARY AND CONCLUSION.

The results of former investigations (Gilson (3), van Wisselingh (7), Priestley (6), regarding the nature of suberin would indicate that it is an aggregate made up of a number of fatty acids in varying degrees of plolymerization. It may also be infered that these acids are in some form in which they are insoluble in the common organic solvents. It is evident that they do not occur as acids or as salts, because none of them are present in the alcoholic extract of cork. When suberized lamellæ are treated with a strong oxidizing reagent such as nitric acid and potassium cholrate these acids fuse together forming a substance commonly referred to as "ceric acid," or cork wax. In the state into which they fuse they manifest a common property toward the action of such organic solvent as hot chloroform, alcohol, ether and benzol, but are insoluble in water.

It could undoubtedly be possible to detect and isolate other fatty acids in the oxidation product of suberin. No attention has been given to the identity of the acid which would be derived from cerine. It has been my particular interest to determine if the three fatty acids reported by Gilson (3) to be present in suberine still maintained their identities in the oxidation product of this substance. This has been done. The term "ceric acid reaction" is evidently misleading and should more properly be designated as the "oxidation reaction," because only a very small part of the fatty acids incorporated in the oxidation product of suberin, comes from the cerine.

There is considerable reason to believe that the composition of suberine may vary in different plants depending upon the conditions under which it is formed. Gilson was not able to isolate any phloïonic acid from elm bark. If this proposition be true, it must follow that the oxidation products must also show wide variation when applied to different types of suberized lamella.

Even with our present conception of the constitution of cutin, there is no reason to believe that the oxidation product of this substance has very much in common with that of suberine. Fremy and Urbain (2) have reported two fatty acids present in cutin of Agave, viz. oleocutic and steareocutic. While the first may resemble in some respects the suberic acid of suberin, the steareocutic appears to be entirely different

from any of the suberogenic acids yet known. The oxidation reaction with respect to cutin requires further investigation.

Possibly, this interpretation of the ceric acid reaction may aid in further investigations of suberized lamellæ, particularly in tissue where the amount of suberin may be relatively small. In such cases there is difficulty at times in differentiating the action of the iodine reagents upon cellulose and suberized lamellæ after macerating in concentrated potassium hydrate. Von Höhnel erred in this connection and von Wisselingh (8) pointed out his mistake. By saponifying the fusion products of oxidation with a 3 to 5 percent solution of alcoholic potash, and cooling, the potassium phellonic salt will precipitate out, if suberin is present. Separate the precipitate from the liquid by filtering and wash several times with 95 percent alcohol. To a small portion of the residue on a glass slide or watch glass add a few drops of chloro-zinc-iodide. If the potassium salt of phellonic acid is present it may readily be detected by the characteristic rose or rose violet color of the disc-like crystals, which commonly form in clumps or aggregates.

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THE DEVONIAN SECTION ON PINAL CREEK, ARIZONA.[1]

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INTRODUCTION.

Pinal Creek originates in the Pinal Mountains of south central Arizona and flows northward through Globe to Salt River, just above the Roosevelt Reservoir. This latter is some twenty miles distant from the mining camps. Solitude Gulch, Bloody Tanks Wash, Lost Gulch, and others of similar character, unite to form an important tributary to Pinal Creek flowing through Miami. A short distance to the east of Globe the drainage flows east and south to the Gila River. Pinal Creek is thus the master stream of the Globe-Miami region. Its ramifying branches cut many fine sections in their steeper portions and the sparseness of vegetation makes these unusually available for study.

Globe is a thriving modern town partially independent of its mining connections. Most of the mines are located to the north and northeast on Buffalo Ridge and in Copper Gulch. A similar mining area lies to the west and northwest of Miami— a much more typical Arizona mining town a few miles to the west of Globe. The mineralized areas of the region are highly faulted and thus constitute a mosaic of formations[2] in which blocks of Devonian limestone take an important part. These are matched up against other Paleozoics, pre-Cambrian metamorphics, intrusives, and volcanics of various ages. The abundance of these faults makes it difficult to piece out the section, especially since portions of it are apparently unfossiliferous. It is probable, therefore, that systems, other than those now included in the general section, may be represented among the remnants.[3]

LOCATION OF SECTION.

The section here discussed is that from which Dr. Ransome collected most of the original Globe Devonian fauna,[4] and one which was found especially fossiliferous during the field work on which the present paper is based. Unfortunately it lacks the exceedingly important fossil, *Pugnax pugnus* which Dr. Ransome found in the Devonian beds of the southeast corner of the Globe quadrangle, and which has been found at various other localities in Arizona.

The Pinal Creek Section is located at an east facing limestone bluff just off the Apache Trail 3¾ miles north-north-west of Globe, and about ¾ of a mile northeast of McLean's ranch. The limestone is faulted and dips as great as 55 degrees S. S. E. were measured. The Devonian is typical Martin limestone[5] lithologically similar to that found on the slopes of Mt. Martin or above the Phelps-Dodge concentrator southeast of Bisbee. This identity is definitely proven by the fauna although at Globe the Martin limestone carries a somewhat different grouping of forms than is characteristic of it in the Bisbee region.

THE PINAL CREEK SECTION.

The following section occurs at the Limestone Bluff on the west side of Pinal Creek, 3¾ miles northwest of Globe, Arizona.

MISSISSIPPIAN.

Lower Tornado Limestone.

Thickness

31. Limestone, highly crystalline, gray, weathering light gray; some chert. These beds contain crinoid stems together with Mississippian corals and brachiopods............100′ 0″

30. Limestone hard, dark gray to bluish; it contains some rather poorly preserved corals and the upper part is commonly crinoidal................................ 50′ 0″

29. Shale, brown to buff, at places reddish and massive. Apparently unfossiliferous........................... 30′ 0″

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[4]Williams, H. S., U. S. G. S. Prof. Paper No. 12, 1903, pp. 40–42, and Ransome, F. L., idem., pp. 44, 45; also U. S. G. S. Folio No. 217, 1923, p. 8, and U. S. G. S. Prof. Paper No. 115, 1919, p. 46.

[5]Ransome, F. L., U. S. G. S. Folio No. 112, 1904, pp. 3–4, and Prof. Paper No. 115, 1919, pp. 45–47.

DEVONIAN.

Martin Limestone.   Thickness

28. Limestone, hard, bluish weathering buff. Fossils abundant.
    Crinoid fragments
    Nortonechinus primus F. & F.
    Atrypa reticularis (Linnaeus).
    Productella hallana Walcott.
    Spirifer hungerfordi Hall.
    Spirifer whitneyi Hall.......................... 7' 8"

27. Limestone, fairly massive, hard, gray to bluish gray, crinoidal.
    Crinoid stems
    Atrypa hystrix Hall.
    Atrypa reticularis (Linnaeus).
    Atrypa spinosa Hall.
    Spirifer hungerfordi Hall....................... 6' 0"

26. Limestone, massive, gray, abundantly fossiliferous.
    The Atrypa bed
    Atrypa hystrix Hall.
    Atrypa reticularis (Linnaeus).
    Atrypa spinosa Hall.
    Spirifer hungerfordi Hall.
    Spirifer whitneyi Hall.......................... 2' 0"

25. Limestone, shaly, gray; somewhat arenaceous and with
    several chert bands, one of which is at the base........ 5' 0"

24. Limestone, shaly, gray to buff, argillaceous.............. 8' 4"

23. Limestone, with shaly partings, gray arenaceous. Crinoid
    segments and a few other fossils occur sparingly.
    Crinoid stems
    Atrypa hystrix (?) Hall.
    Atrypa spinosa Hall.
    Atrypa sublepida Verneuil.
    Stropheodonta sp.
    Spirifer sp................................... 5' 6"

22. Shale, gray and nodular gray limestone which is often shaly.
    Very fossiliferous.
    Alveolites rockfordensis (H. & W.).
    Aulopora cf. iowaensis (H. & W.).
    Aulopora paucitubulata (?) F. & F.
    Cladopora labiosa (?) Billings.
    Cladopora sp.
    Cyathophyllum cf. minus Roemer.
    Heliophyllum solidum (H. & W.).
    Hederella alternata (H. & W.).
    Macgeea solitaria (H. & W.).
    Pachyphyllum cf. levatum W. & F.
    Tabulophyllum sp.
    Codaster sp.
    Hexacrinus n. sp.

Thickness

    Crinoid stems
    Nortonechinus primus F. & F.
    Fenestella diatreta F. & F.
    Atrypa desquamata Sowerby.
    Atrypa duboisi (?) Verneuil.
    Atrypa hystris Hall.
    Atrypa reticularis (Linnaeus).
    Atrypa spinosa Hall.
    Atrypa sublepida Verneuil.
    Cranaella navicella Hall.
    Cyrtia cyrtiniformis H. & C.
    Cyrtina iowaensis F. & F.
    Gypidula cornuta F. & F.
    Leptostrophia canace H. & W.
    Productella hallana Walcott.
    Productella sp.
    Schizophoria striatula (Schlotheim).
    Schuchertella parva (Hall).
    Spirifer orestes H. & W.
    Spirifer subvariocosus H. & W.
    Spirifer whitneyi Hall.
    Spirifer whitneyi gradatus Fenton.
    Spirifer sp.
    Stropheodonta arcuata Hall.
    Stropheodonta sp.
    Strophonella reversa (Hall).
    Bellerophon sp.
    Diaphorostoma (?) sp.
    Floydia concentrica (?) Webster.
    Straparollus circinatus F. & F.
    Tentaculites sp.
    Autodetus slocomi F. & F. . . . . 18' 0"

21. Limestone massively bedded, blue to gray, arenaceous. Somewhat crinoidal and fairly fossiliferous.
    Zaphrentis sp.
    Crinoid stems
    Atrypa reticularis (Linnaeus).
    Spirifer sp. . . . . 12' 6"

20. Shale, gray to brown, weathering buff. Some thin limestone lenses occur in the shales. . . . . 12' 0"

19. Limestone, massive, hard, arenaceous and brown in color. . 2' 8"

18. Limestone, crinoidal, gray, arenaceous.
    Crinoid stems
    Atrypa hystrix Hall.
    Atrypa spinosa Hall. . . . . 2' 0"

17. Sandstone, calcareous, gray, cross-bedded. . . . . 3' 0"

16. Shale, gray weathering to buff. . . . . 10' 0"

15. Limestone, shaly, gray, somewhat crinoidal. . . . . 2' 0"

Thickness

14. Limestone, an uneven layer of gray limestone filled with crinoid stems, many of which are large.
    Crinoid stems and plates .... 0′ 3″
13. Limestone, fairly massive, gray, often nodular and occasionally shaly. This bed is somewhat crinoidal ..... 6′ 0″
12. Limestone, gray, filled with crinoid fragments.
    Crinoid stems and fragments
    Atrypa duboisi (?) Verneuil.
    Atrypa reticularis (Linnaeus).
    Atrypa spinosa Hall.
    Cranaena iowaensis (?) Calvin.
    Leptostrophia canace (H. & W.).
    Schizophoria striatula (Schlotheim).
    Schuchertella coloradoensis Kindle.
    Schuchertella sp.
    Spirifer macbridei Calvin.
    Spirifer whitneyi Hall .... 0′ 3″
11. Limestone, thin bedded, nodular, gray arenaceous, with a few crinoid segments scattered through it.
    Atrypa reticularis (Linnaeus).
    Leiorhynchus nevadaense Walcott.
    Pentamerella sp.
    Schuchertella parva (Hall).
    Stropheodonta sp.
    Spirifer whitneyi Hall.
    Strophonella hybrida H. & W .... 8′ 4″
10. Sandstone, massive, medium to coarse, cross-bedded, hard, gray weathering brown .... 13′ 3″
9. Limestone, shaly arenaceous, gray to brown .... 2′. 0″
8. Limestone, laminated, often thin-bedded, drab to slate colored .... 1′ 10″
7. Limestone, massive, compact, hard, gray, weathering buff .. 4′ 8″
6. Limestone, massive, compact, hard, arenaceous, gray weathering to buff .... 14′ 6″
5. Limestone, massive, compact, hard, brown to pink and gray weathering to buff .... 14′ 0″
4. Shale, argillaceous, gray to purple .... 3′ 0″
3. Limestone conglomerate, hard drab pebbles in a brown matrix, all compact and hard. Some chert .... 4′ 0″
2. Limestone, massive, compact, hard drab, weathering light gray .... 35′ 0″
1. Covered interval to Pinal Creek, at right angles to dip .... 12′ 0″

No fossils were found in numbers 1 to 10 of the above section and these may not belong to the Devonian. About 200 yards down the stream the Pinal schists are exposed and overlying them with angular unconformity are conglomerates and sandstones but these have not been included in the measurements here given.

FAUNAL DISCUSSION.

The Martin limestone fauna, occurring abundantly in bed 22 and sparingly in several of the others in the above section, is characterized by fewer corals and more brachiopods than commonly occur in this formation at Bisbee where several horizons might be described as veritable coral reefs. It is, however, the characteristic Martin fauna in every respect and as such is widely distributed over Arizona. Faulting has cut out so many beds at different localities that the complete section and fauna of the Martin will only be known when the whole south-western Devonian has been systematically covered in one complete and exhaustive study.

The fauna is the same as the typical Iowa upper Devonian and many of the Arizona forms can be matched by species from the Hackberry (Lime Creek) shales at Hackberry Grove, Iowa. Dr. Walcott[6] identified with Iowa forms a number of the species from the Great Basin but the identity of the Arizona fauna with the upper Devonian of Iowa was first pointed out by H. S. Williams[7] and this has been confirmed by others who have had an opportunity to examine such collections as have been made in both places. This relationship is becoming more apparent with every new collection and many of the species mentioned in the section above, when compared with specimens from Hackberry Grove, are indistinguishable. This does not appear to be true of any other fauna with which the Hackberry has been compared. As observed by C. L. and M. A. Fenton,[8] there is a certain faunal relationship existing between the Hackberry and the upper Devonian of other parts of North America. This was long ago recognized by C. S. Prosser and others, and has been the basis on which the supposed identity of some closely related forms has been established. It has likewise influenced the distribution of land and sea on the paleographic maps of the time.

In Dr. Walcott's Devonian collection from the Eureka and White Pine Districts of Nevada,[9] more than half of the species are from the lower part of a 6000 foot limestone. More than half of the remainder, or 61 species, are from the upper part of the same limestone. Many of these latter, and about

[6]U. S. G. S. Mono. VIII, 1884, pp. 274–278.
[7]U. S. G. S. Prof. Paper XII, 1903, p. 42.
[8]The Stratigraphy and Fauna of the Hackberry Stage of the Upper Devonian, 1924, p. 17.
[9]U. S. G. S. Monograph VIII, 1884, p. 4–8, 274–278. Also Monograph XX, 1892, pp. 325–330.

a third of those from the overlying 2000 feet of shales (White Pine), indicate the presence of the Martin fauna. Dr. Walcott himself says that "there is little doubt but that future collections from the area of the Great Basin will give a very complete series of species, and still further increase the number of species common to the eastern and central (or Atlantic and Mississippi) areas and the western or Rocky Mountain area."[10] There is thus forecast the possibility of additional and larger collections to be made from the higher Devonian beds of Nevada and the ultimate segregation of the Martin fauna, the presence of which is certainly suggested by the list of species already known from that region. The success of such an undertaking has become more probable since J. S. Diller[11] found part of the Martin fauna in northern California and its wider distribution becomes evident.

Although many Hackberry species resemble those from other regions, notably the East and the North, "close examination shows that, with few exceptions, they present apparent and constant differences."[12] It is probable that this is more applicable to the brachiopods but it may eventually be found to be equally true of many of the other fossil forms found throughout the southwestern Devonian province. If this is a fact, as it appear to be, the Arizona forms identified as *Schizophoria striatula* Schlotheim should be returned to *S. iowaensis* (Hall) and the western *Pugnax pugnus* (Martin) should be either *Pugnoides calvini* F. & F. or *Pugnoides solon* (T. & S.) as Fenton and Fenton[13] have done with the Hackberry forms in Iowa. The Martin fauna, when completely known, will probably exceed the Hackberry in richness of species, but the Iowa fauna is now much better known and mostly in a state of perfect preservation. This latter is only partially true of the Martin fauna. The Hackberrry of Iowa should therefore be used as the standard of comparison for this southwestern or Martin fauna and for all others supposed to contain identical species. A related fauna, probably a later recurrent phase of it, occurs in the Ouray limestone of Colorado[14] and abundantly in the Percha shale of the southwestern part of New Mexico.[15]

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[10]U. S. G. S. Monograph VIII, 1884, pp. 7, 8.
[11]Am. Jour. Sci., 4th Ser., Vol. XV, 1903, p. 348.
[12]Fenton, C. L., and Fenton, M. A., Op. cit., p. 17.
[13]Op. cit., pp. 83–85, 125–129.
[14]Kindle, E. M., U. S. G. S. Bull. 391, 1909, pp. 1–14.
[15]Gordon, C. H., and Graton, C. L., Am. Jour. Sci., 4th Series, Vol. XXI, 1906, p. 394–395. Idem Abs. Jour. Geol., Vol. XV, 1907, pp. 91–92. Also Lindgren, /., Graton, L. C., and Gordon, C. H., U. S. G. S. Prof. Paper 68, 1910, p. 228.

The territory intervening between the region in which the Martin occurs and the Iowa-Missouri Devonian region is unmarked by outcrops of this age. A large part of that territory, however, has been so frequently depressed and covered by marine invasions, bringing in the later sediments, that any existing Devonian remnants are deeply buried beneath Mississippian or later formations. Although it is probable that species occur in Arizona which may not be found in Iowa, and vice versa, still the relationship between the Martin fauna and that of the Hackberry of Iowa is too intimate to admit of any other interpretation than a direct communication between the two. Some of the Martin-Hackberry species, or closely related forms, reached the eastern part of the North American continent by late Devonian time, but the fauna as a whole did not get farther in that direction than Iowa, its most characteristic species being entirely lacking in the New York upper Devonian. The probability is, therefore, that the migratory route to the East, for such species, or their varieties, as reached northern Michigan and New York, was not by way of Iowa but by some more roundabout way, such as the Mackenzie valley, where these same southwestern species that are absent in New York also appear to be wanting.

It has been pointed out, especially by Professor Schuchert,[16] that the southwestern upper Devonian is an Eur-Asiatic fauna. However, it should also be noted that when the epicontinental sea, in which this fauna was prevalent, extended uninterruptedly from the Pacific across northern Mexico, California, Nevada, and Arizona northeastward to Iowa and Missouri, it was one of the great Devonian embayments of the continent and dwarfed to comparative insignificance the eastern Devonian invasion with the fauna that is usually regarded as more or less typically American. The Martin-Hackberry fauna is therefore as much at home on this continent as it is in Europe and only a little less so here than in Asia. It would probably more nearly express the truth to consider the whole region from the central and western part of North America, across Asia to Europe as one great Devonian province and add the name of this continent to that used by Schuchert, making it the Eurasio-American province.

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[16]Am. Jour. Sci., 4th Ser., Vol. XV, 1903, p. 348.

THE STRUCTURE OF THE DIGESTIVE SYSTEM IN CREOPHILUS VILLOSIS

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University of Omaha.

INTRODUCTION.

The beetles used in this study were procured at the Columbus, Ohio, Packing House, where they lived in and around an open shed, "the hair house," where fly larvæ were abundant in masses of hair. Here they were found in large numbers in early fall. Occasionally one or two were obtained from fly larvæ infested meat placed out of doors at the Ohio State University. This large black staphylinid with silvery white markings is usually known as *Creophilus villosis* (Grav.) but is listed by Long as variety *villosis* of the species *Creophilus maxillosis* (L.).

I wish to express my appreciation to Doctor C. H. Kennedy under whose supervision the work has been carried on.

THE GROSS ANATOMY OF THE ALIMENTARY CANAL OF THE ADULT.

The alimentary tract is relatively short in correlation with the carniverous habits of the beetle. It extends as an almost straight tube only slightly longer than the body itself. (Fig. 1).

The *fore-intestine* begins with a small pharynx limited to the anterior part of the head. This narrows quickly into a slender oesophagus extending into the prothorax where it gradually widens into the gizzard. In the mesothorax the gizzard is constricted at the beginning of the mid-intestine or stomach.

The *mid-intestine* is large in diameter and comprises about one-half the length of the entire tract. At the posterior end it loops back upon itself for a short distance. The stomach is covered from beginning to end with large and conspicuous pipillaform crypts which give a dense white appearance.

The *hind-intestine* is transparent enough so that often the chalky white contents can be seen being moved about by peristaltic action. This action often continues for a number of

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minutes after the beetle is chloroformed and placed in normal salt solution. Four Malpighian tubules arise at the beginning of the hind-intestine. They are long and coil about the alimentary tract and fat bodies. The hind-intestine has only two visible regions. The most anterior of these (ileum) is slender and short and is usually looped or folded upon itself. The posterior part (colon) loops once then extends caudad. The rectum is not differentiated to outward appearance from the colon.

Terms such as ileum, colon, and rectum are used rather arbitrarily because these parts vary too much in form, structure, and proportion in various species of beetles to be exactly homologyzed.

THE HISTOLOGICAL STRUCTURE.

Pharynx.—The mouth opens into a short, thickly chitenized, muscular pharynx (Fig. 5). The intima is thick, almost transparent, and has a rough surface from which short hair-like processes of chiten extend in imbricated rows, (Fig. 3). These hairs are found on about one-half the inner surface being lacking on the ventral side. The cuboid epithelial cells secreting the intima are very small. The muscles do not form a definite inner longitudinal layer and an outer circular layer, but show a confusion of pharyngial muscles and attachment muscles. The latter extend diagonally out to the chiten of the head and serve to expand the pharynx.

Oesophagus.—The intima of the oesophagus is much thinner than that of the pharynx and is thrown into a number of irregular, shallow folds, (Fig. 6). There are no hairs throughout the length of the oesophagus. The epithelium consists of a layer of small cells. Longitudinal muscles are sparsely distributed. Near the base of the pharynx they form a complete covering of the epithelial cells but further back they become scattered and a cross section may show from one to four. Circular muscles form a complete outer layer two or three muscles thick.

Gizzard.—As the oesophagus gradually widens into the gizzard the intima again thickens and hairs appear which are larger and longer than those in the pharynx. These are arranged in rows on and between slight ridges of chiten which encircle the pharynx giving its inner surface a ringed appearance, (Fig. 4). The hairs extend into eight groups which meet in

the center and twirl about, (Fig. 2). They point slightly caudad, probably being pushed back by in-coming food. The epithelium cells are small and often indistinct. Connective tissue joins the epithelium cells with the longitudinal muscles which fill in the eight folds, (Fig. 7). These are of two distinct sizes, the larger muscles being on the outside of each fold, and the smaller muscles filling up the inner part. Two or three layers of large circular muscles surround the whole.

Oesophageal Valve.—The end of the fore-intestine is marked by the oesophageal valve, (Fig. 9). Here the eight folds lose their characteristic shape, become more rounded, and are reduced to from five to seven. The intima changes to a smooth, hairless, slightly thickened covering of the valve which ceases rather suddenly at its posterior end. Epithelial cells become large and elongate. The muscles do not retain their distinct layers but intertwine as they form their attachments to the valve.

Mid-Intestine.—In Creophilus the mid-intestine is distinct in a number of ways.

The epithelial cells reach out through the muscular wall of the stomach as a loose pyle of long crypts measuring as much as eighty mu in length, (Fig. 10). At the outer end of each crypt is a nidus of cells consisting almost wholly of large nuclei. The cells that originate in the nidi make their way down the crypts and become the large secreting cells. At the extremity each crypt is solid but nearer the inner surface of the stomach the cells do not reach entirely to the center in some places and so form irregular spaces in the middle. Korschelt (*Bearbeitung Einheimischer Tiere. I Monographie. Der Gelbrand Dytiscus Marginalisl*) speaks of these spaces as vacuoles and states that they contain digestive fluids. The epithelial cells not only extend out from the muscle wall but also develop folds into the lumen of the stomach. Secretion is holocrine so that at the inner ends of the crypts cells are constantly being broken down to liberate digestive enzymes, and as they are sloughed off new cells take their place. As is usual with secreting cells the cytoplasm as well as the nucleus stains a deep blue in Delafield's Hemotxylin.

The muscular layer cannot be said to surround the epithelial cells but is sunk in among the crypts forming a perforated structure through whose openings the crypts extend. Back of the oesophageal valve the layers have changed position, the

circular muscles being on the inside and the longitudinal
muscles covering them externally. The longitudinal muscles
branch occasionally and do not run very regularly because of
interference of the crypts. The circular layer is thicker and is
matted together with minute branched strands running all
through it but which are more concentrated on its inner surface.
These small strands show no striations and sometimes seem to
extend from the circular muscles and sometimes from cells
lying loosely in the layer, (Fig. 11, con.). The first interpre-
tation of this mat of branching hair like fibers was that they
were minute branched muscle fibres or perhaps connective
tissue cells. Later Mr. Warren Miller found a similar layer
in the stomach wall of a Meloid beetle, Meracantha, where
they were demonstrated to be tracheoles. This is probably the
correct interpretation of this layer in Creophilus. Each crypt
has a layer of these strands covering it. Larger fibres (but
considerably smaller than the ordinary striated muscle) extend
lengthwise, twelve or more running out each crypt. The
space between these is filled by very fine strands which encircle
the crypt, (Fig. 8). The two together form a complete though
thin covering.

  Malpighian Tubules.—The beginning of the hind-intestine
is marked by the Malpighian tubules, (Fig. 14). They are
four in number arising close together at the posterior end of the
stomach at almost the same level from which the last crypts
extend. They are composed of huge cells, large nucleated and
of indistinct cell walls, surrounding a lumen and bounded on
the outside by a thin membrane of connective tissue.

  Pyloric Valve.—This valve is composed of a ring of elongate
epithelial cells thrown into a number of folds, (Fig. 12). They
are covered by a thin intima which begins at the anterior end
of the valve and lines the entire hind gut. Here again the
muscles intertwine so that there is no distinct inner or outer
layer. Muscles branch as they run obliquely to the epithelial
cells pulling them out to allow the opening of the valve.

  Ileum.—In the iluem the intima is also thin and closely
applied to the epithelial cells which are fairly small and regular.
The epithelium is thrown into many irregular folds, (Fig. 13).

  Muscles form a very thick layer about the ileum. There is
no definite longitudinal layer but the muscles run more or less
obliquely in every direction. Near the anterior end there are
many muscles which branch to form narrow attachments to

the epithelial cells, and by contracting serve to pull out the folds, thus enlarging the ileum, (Fig. 12).

Colon.—The ileum is very short and suddenly widens into the colon, (Fig. 15). The intima continues as a very thin layer and the epithelial cells become much larger. The folds become more regular. At first there are from five to seven folds but further back these increase to from twelve to fifteen, (Fig. 17). About half way down the colon the folds become less distinct and widen out to form six or seven shallow corregations, (Fig. 16).

Usually in insects the hind-intestine has three layers of muscle, an inner circular layer, a middle longitudinal layer, and an outer circular layer. In Creophilus the longitudinal muscles seem to be lacking so the circular muscles are not differentiated into two layers. Throughout the muscle layer of the colon there are many tracheoles as described in the walls of the stomach, the circular muscles being bound together by them. The layer is also held closely together by branching of the muscles so that they twine about each other.

In the alimentary tract branching of the muscles appears to perform three different functions. In the stomach branching serves to circumvent the crypts. In the pyloric valve and ileum branches multiply the number of attachments to the epithelial cells. While in the colon branching binds the muscles closer together.

Rectum.—Near the anus the intestine narrows to form the rectum, (Fig. 18). The intima is very much thickened and roughened at the surface. There are six or seven epithelial folds which are drawn close together. The circular layer of muscles is thicker here than in the colon.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Entire alimentary tract.
Fig. 2. Cross-section through gizzard.
Fig. 3. Portion of chiten of gizzard showing arrangement of hairs.
Fig. 4. Portion of chiten of pharynx showing arrangement of hairs.
Fig. 5. Longitudinal section through pharynx.
Fig. 6. Cross-section through oesophagus.
Fig. 7. Portion of Fig. 2.
Fig. 8. Cross-section through crypt near base showing covering of connective tissue.
Fig. 9. Longitudinal section through oesophageal valve.
Fig. 10. Longitudinal section through stomach showing one crypt.
Fig. 11. Cross-section through crypts near base, showing muscle and connective tissue.

PLATE II.

Fig. 12. Longitudinal section through pyloric valve.
Fig. 13. Cross-section through ileum.
Fig. 14. Cross-section through pyloric valve, showing Malpighian tubules.
Fig. 15. Longitudinal section through ileum and colon.
Fig. 16. Cross-section through anterior part of colon.
Fig. 17. Cross-section through posterior part of colon.
Fig. 18. Cross-section through rectum.

Key to Abbreviations.

c. Mus...............Circular Muscle.
Con.................Tracheoles.
E....................Epithelium.
Giz..................Gizzard.
Int..................Intima.
L. Mus..............Longitudinal Muscle.
Malp................Malpighian tubule.
Mus.................Muscle.
Oes.................Oesophagus.
Ph..................Pharynx.
St...................Stomach.
Rect................Rectum.

FIG. 12

FIG. 13

FIG. 14

FIG. 15

FIG. 16

FIG. 17

FIG. 18
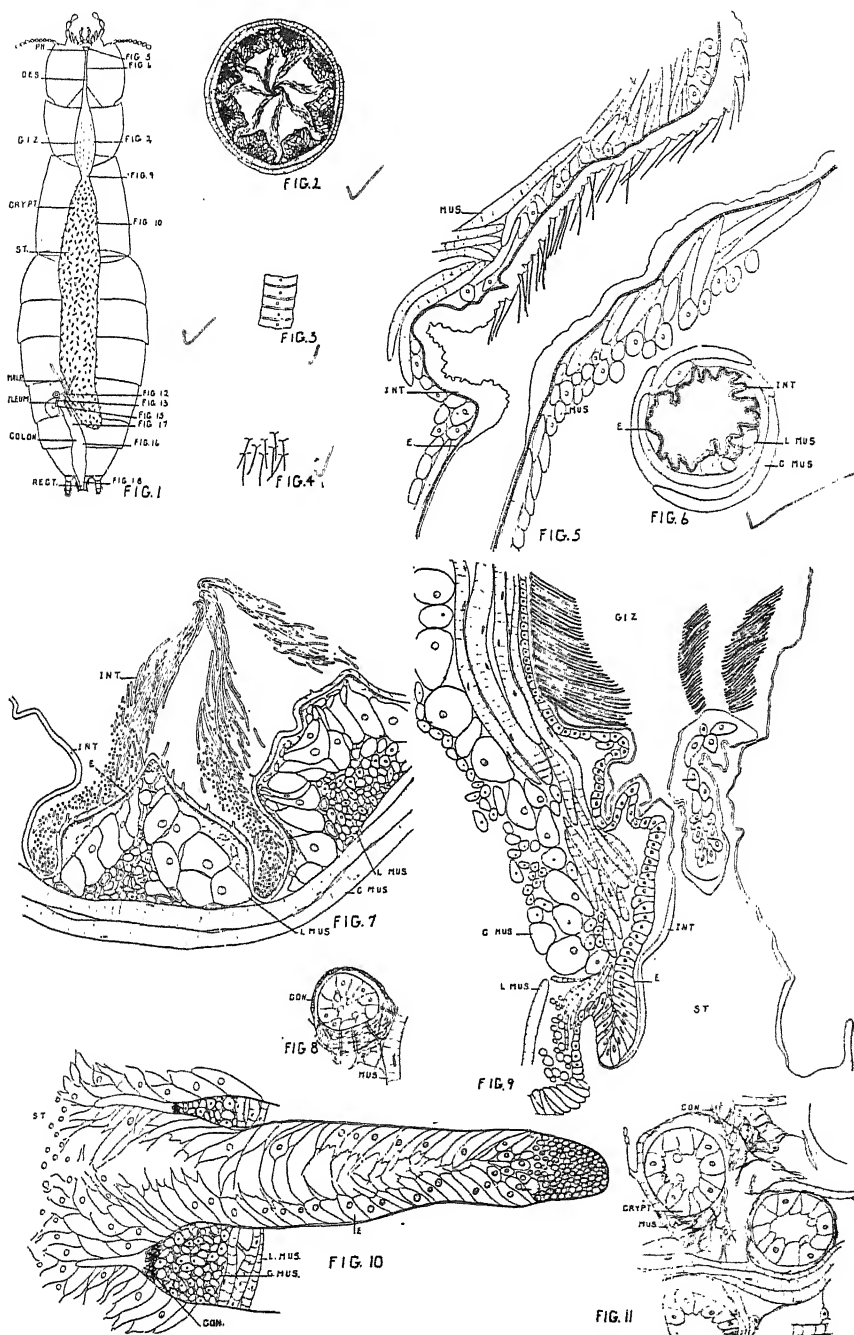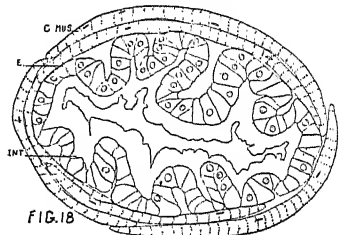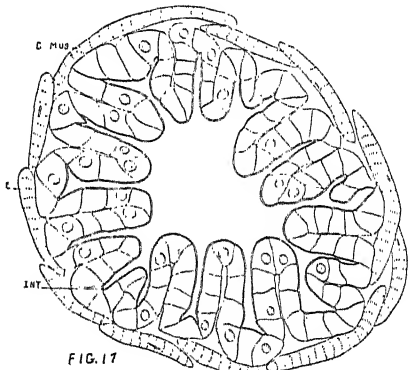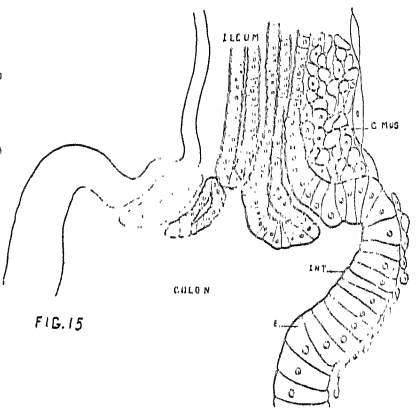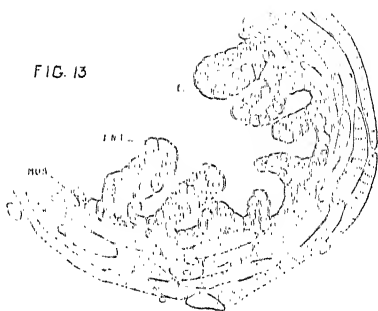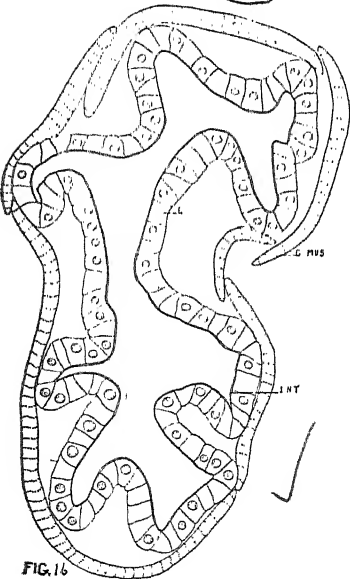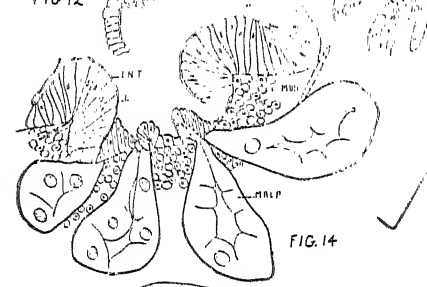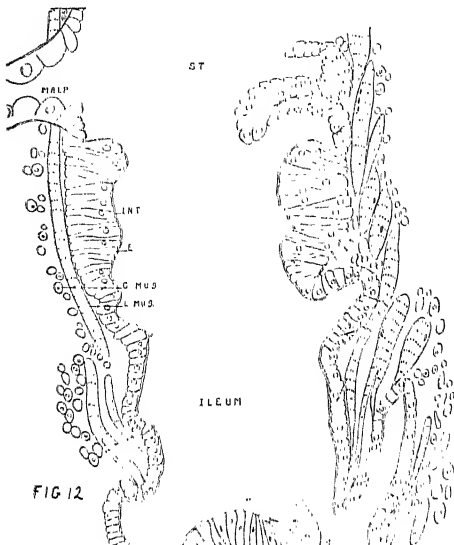
CONCERNING SOME NORTH AMERICAN WATER-STRIDERS WITH DESCRIPTIONS OF THREE NEW SPECIES

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Recent publications on North American water-striders have resulted in a need for revised distributional data. This is especially true for certain species of the family Gerridæ. To illustrate, eight or nine different species have been placed under the name of *Gerris marginatus* Say in the literature. The following notes are based on the water-striders in the collections of Iowa State College, the University of Minnesota, the University of Illinois, the Montana State College, Professor H. E. Summers, Mr. Wm. J. Gerhardt, and the authors.

Gerris remigis Say. (Fig. 1, a).
Say, Thomas, Heter. N. Harm., p. 35, 1832.
Stal, C., Frey, Eugen. Resa. Ins. p. 264, 1859 (*Gerris orba*).
Uhler, P. R., Am. Jl. Sci., ser 3, I, p. 105, 1871 (*Hygrotrechus robusta*).

This is the most common and widespread gerrid in North America. It frequents the wider portions of small streams but is not uncommon in creeks, rivers, ponds and lakes. Both winged and wingless forms occur throughout its entire range. The color and size, even in specimens taken from the same colony, show marked variations. The spines at the ends of the connexiva vary in length. A cotype of *Gerris orba* Stal kindly sent to us by Dr. Yngve Sjostedt, Intendent of the Naturhistoriska Riksmuseet at Stockholm, is before us; it is a typical *G. remigis*. This specimen and the type series at Stockholm bear labels " = *remigis* Say, teste Kirkaldy." The male genitalia of the cotype of *G. orba* Stal (snyn. of *G. remigis* Say) is figured. A long series of specimens taken at the type locality of *Gerris robusta* Uhler by Mr. E. P. Van Duzee of the California Academy of Science are also typical examples of *G. remigis*. Furthermore, specimens determined by Uhler himself as *G. robusta* are identical with *G. remigis*. The type of *G. robusta* (a damaged female, according to the original description) cannot be found in Uhler's collection, the National Museum, or the Museum of the California Academy of Science. After having studied several hundred specimens of *G. remigis*, some of which have come from every state in the union (with the exception of one or two), Canada and Mexico, the writers feel that both *G. orba* Stal and *G. robusta* Uhler must stand as synonyms of *Gerris remigis* Say.

Gerris nyctalis Drake and Hottes. (Fig 1, b).
Specimens are at hand from the following localities: COLORADO—Dolores, Estes Park, Garrison, Ft. Garland, Pagosa Springs, Placerville, North Park, South Fork, and Veta Pass, August, 1925, C. J. Drake. WASHINGTON—Lake Sutherland, August 8, 1927, C. R. Crosby. CALIFORNIA—Fresno, June 20, 1926, C. J. Drake. IDAHO—Caldwell, July 9, 1926, C. J. Drake. MONTANA—Bozeman, R. A. Cooley.

Gerris nebularis Drake and Hottes.   (Fig. 1, c).

In addition to the type localities specimens are at hand from the following states: SOUTH CAROLINA—Clemson, July 9, 1914, F. H. Lathrop. ALABAMA—Birmingham, March 21, 1925, R. Cecil. TENNESSEE—Knoxville, June, 1890, H. E. Summers. MISSISSIPPI—Charleston, Sept. 7, 1925, H. M. Harris; A. and M. College, June 24, 1914, R. W. Harned. NEW YORK—Syracuse, July 26, 1921, C. J. Drake. IOWA—Mt. Pleasant, July 14, 1927, Harris and Johnston. Kansas—Ottawa, May 20, 1925, B. M. Harrison.

Gerris insperatus Drake and Hootes.

OHIO—Wellington, August 7, 1890, H. E. Summers. ILLINOIS—Homer, April 27, 1907. NEW YORK—Cranberry Lake, July 22, 1919, C. J. Drake; Ithaca, May 4, 1888, H. E. Summers. ALABAMA—Birmingham, March 21, 1925, R. Cecil. TENNESSEE—Knoxville, March 17, 1889, H. E. Summers. SOUTH DAKOTA—Pierre, April 22, 1919. This species ranges throughout the eastern portion of the United States, south into Mexico and west to Colorado.

Gerris incurvatus Drake and Hottes.

OREGON—Corvallis, June 26, 1926, C. J. Drake. BRITISH COLUMBIA—Victoria, July 4-7, 1926, C. J. Drake. CALIFORNIA—Fresno, June 20, 1926, C. J. Drake. IDAHO—Moscow, April 3, 1913, J. M. Aldrich; Caldwell, July 8, 1926, C. J. Drake. MONTANA—Bozeman, 1906 and Gallatin Co., June 3, 1902, R. A. Cooley. *G. incurvatus* is very common in the northwest and along the Pacific coast. Its known range extends east into Illinois.

Gerris incognitus Drake & Hottes.

OREGON—Corvallis, June 26, 1926, C. J. Drake. CALIFORNIA—Fresno, June 20, 1926, C. J. Drake. IDAHO—Moscow, April 1913; Caldwell, July 9, 1926, C. J. Drake. MONTANA—Gallatin Mtns., August 25, 1925, and Big Fork, August 20, 1912, R. A. Cooley. This is one of the most common gerrids in the northwest. It has been frequently confused in collections with both *G. marginatus* and *G. gillettei.*

Gerris comatus Drake and Hottes.

NEW YORK—Ithaca, August 26, 1890, H. E. Summers; Buffalo, E. P. Van Duzee. ILLINOIS—Algonquin, November 2, 1908. MINNESOTA—North Branch, June 17, 1922, C. E. Mickel; Mora, June 16, 1922, and Detroit, July 2, 1922, W. E. Hoffman. IOWA—Albia, Ames, Atlantic, Cedar Falls, Clear Lake, Elkader, Lovilia, Ft. Dodge, McGregor, Mason City, Oelwein, Red Oak, and Webster City, June-August, 1927, Harris and Johnston. SOUTH DAKOTA—Brookings, April 28, 1921, H. C. Severin. NEBRASKA—Big Springs, August 26, 1925, C. J. Drake. COLORADO—Dolores, Garrison, Hudson, Mesa Verde National Park, Pagosa Springs, South Fork, Wray and Veta Pass, August, 1925, C. J. Drake. MONTANA—Bozeman, August, 1913, R. A. Cooley. *G. comatus* has been confused in practically every collection and in the literature with *G. marginatus* Say. It is one of the most common species in eastern Canada and United States, occurring from Colorado to the Atlantic Coast.

Gerris comatus var. *mickeli* Drake and Hottes.

A female was taken in a swamp at Corvallis, Oregon, June 26, 1926, and another at Wray, Colorado, August 4, 1925, by C. J. Drake. These two specimens and the types from Minnesota are brachypterous. The male is unknown. This variety differs from typical *G. comatis* in having longer and more numerous hairs on the connexival spines and a stripe along each side of the pronotum in front. Male specimens may prove it to be a distinct species.

Gerris marginatus Say.

TENNESSEE—Knoxville, June 13, 1891, H. E. Summers. NORTH CARO-LINA—Southern Pines, March 2, 1916. OHIO—Delaware, July 12, 1916, C. J. Drake. NEW YORK—Buffalo, 1890, E. P. Van Duzee. IOWA—Ames, Albia, Atlantic, Burlington, Cedar Falls, Clear Lake, Donnelson, Elkader, Farmington, Ft. Dodge, Ft. Madison, Jewell, Mason City, McGregor, Oelwein, and Red Oak, June-August, 1927, Harris and Johnston. KANSAS—Lawrence. MINNESOTA—Rochester, June 15, 1922, C. E. Mickel. COLORADO—Wray and Mesa Verde National Park, August, 1925, C. J. Drake. MISSISSIPPI—Charleston, August 31, 1925, H. M. Harris. WEST VIRGINA—Morgantown, July, 1927, L. E. Dills. TEXAS—Weslaco, July 17, 1927, M. McPhail. *G. marginatus* probably occurs in every state in the union. Several species have been confused with it in literature.
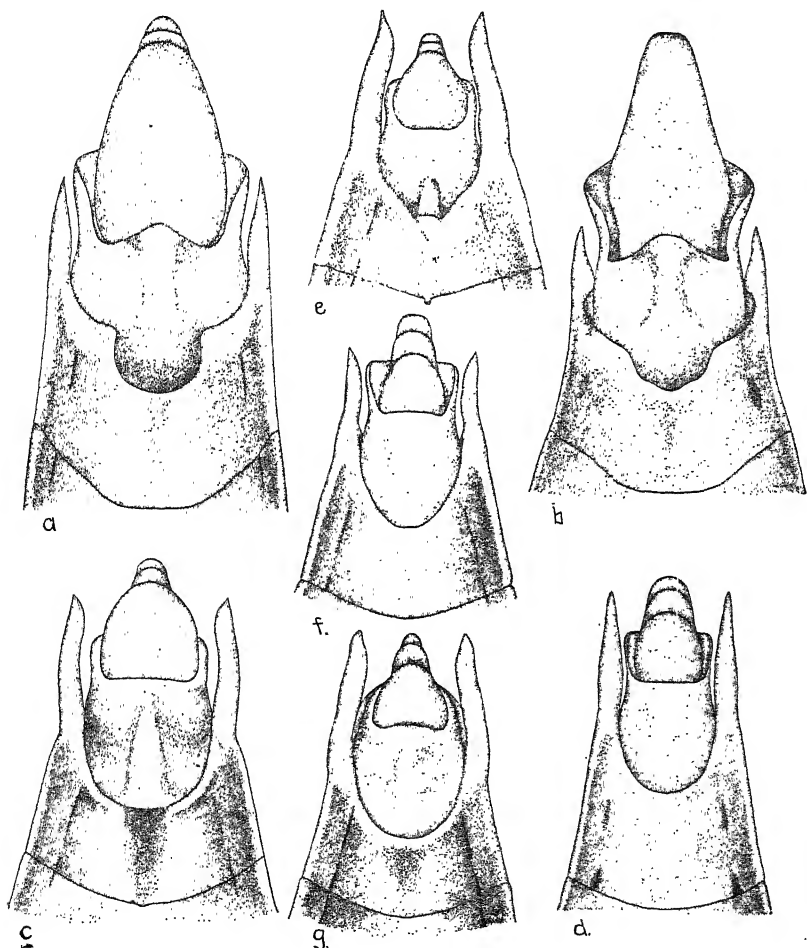
Fig. 1. Ventral aspect of male genitalia of the larger species of *Gerris*. a, *Gerris remigis* Say; b, *G. nyctalis* D. & H.; c, *G. nebularis* D. & H.; d, *G. notabilis* D. & H.; e, *G. uhleri* D. & H.; f, *G. rufoscutellatus* Latr.; g, *G. conformis* Uhl. (Drawn by Miss Kathleen Doering).

Gerris pingreensis Drake and Hottes.

COLORADO—Pingree Park and Estes Park, August 20-24, 1925, C. J. Drake. IDAHO—T. D. A. Cockerell. This species is common in the ponds and lakes in the high altitudes of the Rocky Mountains.

Gerris alacris Hussey.

OHIO—Hocking Co., May 10, 1916, C. J. Drake.

Gerris gillettei Lethierry and Severin.

COLORADO—Dolores, Ft. Garland, Garrison, Pagosa Springs, Pingree Park, Trinidad, South Fork, Wray and Veta Pass, August, 1925, C. J. Drake. MONTANA—Bozeman, June 1, 1924, R. A. Cooley. CALIFORNIA—Fresno, June 20, 1926, C. J. Drake. TEXAS—Rock Island, July 10, 1922, Grace O. Wiley. UTAH—Saltair, July 5. This is a western species and is found in the Rocky Mountain states and along the Pacific slope.

Gerris buenoi Kirkaldy.

NEW YORK—Rochester, September 1, 1890; Buffalo, September, 1886, E. P. Van Duzee. ONTARIO—Ottawa, April 26, 1922, C. H. Curran. MASSA-CHUSETTS—Forest Hills, November 1, 1915, H. M. Parshley. IOWA—Ames, Cedar Falls and Mt. Pleasant, July 14, 1927, Harris and Johnston. SOUTH DAKOTA—Brookings, April 28, 1921, H. C. Severin. COLORADO—Ft. Collins, August 23, 1925, C. J. Drake. OREGON—Corvallis, June 26, 1926, C. J. Drake. BRITISH COLUMBIA—Victoria, July 4-7, 1926, C. J. Drake. *G. buenoi* is a transcontinental species and is very common in southern Canada and northern United States.

Gerris notabilis Drake and Hottes.　(Fig. 1, d).

CALIFORNIA—Fresno, June 20, 1926, C. J. Drake. WASHINGTON—San Juan Island, July 2, 1926, C. J. Drake. IDAHO—Moscow, 1913. MONTANA—Shields River, July 17, 1925. COLORADO—Dolores, Garrison, Mesa Verde National Park, South Fork, August, 1925, C. J. Drake. IOWA—Ames, July, 1925, C. J. Drake. This is a very common species in the Rocky Mountains and along the Pacific coast. It ranges as far east as central Iowa. The much longer legs and the different genital characters separate it from *G. rufoscutellatus*.

Gerris canaliculatus Uhler.

FLORIDA—Gainesville, July 14, 1918, C. J. Drake. MISSISSIPPI—Charleston, September 9, 1925, H. M. Harris; Natchez, September 8, 1924, H. M. Harris; Vicksburg, Port Gibson, Woodville, McComb and Agr. College, July, 1921, C. J. Drake. ARKANSAS—Little Rock, August 30, 1926, H. M. Harris. OHIO—Rockbridge, September 30, 1916, C. J. Drake. NEW YORK—Ithaca, August, 1890, H. E. Summers; Syracuse, 1917-21, C. J. Drake. ILLINOIS—Oaktown, August 15, 1905; Pulaski, July 10, 1907; Dubois, August, 1913.

Gerris argenticollis Parshley.

Sugar Grove, Ohio, July 28, 1916, C. J. Drake. Agr. College, Mississippi, April, 1916, R. W. Harned. Chicago, Illinois, W. A. Gerhard.

Gerris mexicanus Champion.

Two specimens, Cuernavaca, Mexico, May 15, 1898.

Gerris cariniventris Champion.

Tegucigalpa, Honduras. Four specimens, which agree with two of Champion's cotypes before us.

Tenagogonus hesione Kirkaldy.

OHIO—Columbus, Rockbridge, and Buckeye Lake, 1916, C. J. Drake. MISSISSIPPI—Summit, September 4, 1926, and Charleston, September 8, 1926, H. M. Harris; McComb, Fayette, and Vicksburg, July, 1921, C. J. Drake. FLORIDA—Gainesville, May-July, 1921, C. J. Drake. TEXAS—Bryan, October 25, 1927, H. G. Johnston. ILLINOIS—Havana, October 4, 1910; Dubois, August 13, 1917. The long-winged form is common in Mississippi and Florida but uncommon in the northern states. One winged example from Columbus, Ohio, is at hand.

Tenagogonus hyalinus Fabricius.

MEXICO—Minatitlan, February 1, 1892, H. Osborn. WEST INDIES—Grenada, September 25, 1891, H. E. Summers.

Tenagogonus quadrilineatus Champion.

MEXICO—Colima, L. Conradt. HONDURAS—Tegucigalpa, July 14-19, 1917, H. G. Dyer.

Trepobatopsis denticornis Champion.

TEXAS—Clifton, May 30, 1907. This is the first known record of this insect occurring in the United States. Another specimen from Cantarina, Monterey, Mexico, April 10, 1910, is before us. It has the wings broken off.

Trepobates floridensis, n. sp.

Distinctly smaller than any other known species of the genus. Body above black, an elongate spot on either side and an interrupted line on posterior margin of mesonotum, a small spot on each side and more or less of basal margin of pronotum, a line on each side of head above the eyes and the posterior margin between these lines yellowish brown. Body beneath and a broad stripe on each side of mesonotum yellowish. Rostrum reaching a little beyond anterior coxæ, dark brown, the basal segment yellowish. Antennæ dark brown, yellowish at base segment I long, slightly curved, subequal to II and III conjoined; II very slightly shorter than III.

Pronotum practically twice as broad as long, impressed on each side of the disc. Mesonotum broadly and rather uniformly impressed along the median line, the posterior margin truncate. Legs much shorter and slenderer than in *T. pictus* Uhl., dark brown; the anterior tibiæ strongly curved, slenderer at base and apex. Connexivum moderately broad, concolorous. Abdomen above without spots. Length 2.5 mm.; width 1.0 mm.

Holotype, apterous male, East Florida, collection of authors. The much smaller size and the shorter and slenderer legs and antennæ separate this species from any of its congeners. The intermediate legs and the second antennal segment, as in *T. pictus*, are without long hairs. The proportional lengths of the antennal segments in these two species are: *pictus*, I:II:III:IV—80:43:49:47; *floridensis*, 50:24:26: (missing).

Rheumatobates tenuipes Meinert.

MARYLAND—Glen Echo, September 8, 1893. MISSISSIPPI—Charleston, September 8, 1926, H. M. Harris. FLORIDA—Gainesville, J. M. Watson, TENNESSEE—Knoxville, June 5, 1890, H. E. Summers.

Rheumatobates trulliger Bergroth.

TENNESSEE—Knoxville, June 15, 1890, H. E. Summers. MISSISSIPPI—Charleston, September 7, 1925, H. M. Harris; Shipman, August 2, 1921, C. J. Drake. A wingless male and female from Shipman, Miss., have been compared with the type of *R. trulliger* for the authors by the late Dr. E. Bergroth.

Rheumatobates hungerfordi Wiley.

TEXAS—Weslaco, July 17, 1927, M. McPhail; Bryan, October 25, 1927, H. G. Johnston.

Rheumatobates rileyi Bergroth.

MISSISSIPPI—Charleston, September, 1925 and 1926, H. M. Harris. FLORIDA—Gainesville, J. R. Watson. OHIO—Cuyahoga Co., and Berea, July, 1914, C. J. Drake. IOWA—Ames, Albia, Cedar Falls, Oelwein and Mt. Pleasant, June-August, 1927, Harris and Johnston. ILLINOIS—Havana, July 7-13, 1917.

Mesovelia cryptophila Hungerford.

IOWA—Wapello, August 5, 1926, H. M. Harris. MISSISSIPPI—McComb, September 8, 1924, H. M. Harris.

Microvelia orcadis, n. sp.

Elongate, narrow, fusiform; dark fuscous black, the sides of connexiva a little lighter. Pronotum with a broad transverse rufofulvous band in front, the abdominal tergites each with a pale brownish spot. Head with the usual, shiny, impressed median line and blackish spots above the eyes. Antennæ about one-half as long as body, pilose, with a few scattered setæ, dark brownish black; segment I paler and tinged at base with testaceous, stoutest, slightly curved; the proportional lengths of segments:—I:II:III:IV = (male) 17:14:19:25, (female) 17:18:25:30. Rostrum stout, brownish testaceous, the terminal segment blackish, reaching a little beyond the middle of mesonotum.

Pronotum short, coarsely pitted behind, the basal margin slightly emarginate. Mesonotum about half as long as pronotum. Legs brownish, the coxæ, trochanters, and tibiæ beneath lighter; tibiæ clothed with numerous long setæ. Connexivum very broad, broader in female than in male. Abdomen with the last tergite truncate at apex in male, rounded in female. Body beneath flattened, yellowish to dark brown. Length (male) 2.21 mm.; (female) 2.78 mm.; width (male) .79, (female) .93 mm.

Holotype, apterous male, and *allotype*, apterous female, Estes Park, Colorado, August 24, 1925. *Paratypes* (253 specimens), taken with type, also at Fort Collins, Colorado, August 23, 1925, Placerville, Colorado, August 15, 1925, and Dolores, Colorado, August 15, 1925, C. J. Drake, collector. Types in collection of authors. Paratypes in collections of Iowa State College, University of Kansas, U. S. National Museum, British Museum of Natural History, H. H. Knight and the authors.

In many of the specimens some of the dorsal segments of abdomen and connexiva bear flattened silvery hairs which are grouped in patches. This species is perhaps most closely related to *M. setipes* Champion. However, it is slightly smaller and the setæ like hairs on the tibiæ are

more numerous. The proportional lengths of the antennal segments of the males of *M. oreadis* are also much different.

Microvelia irrasa, n. sp.

Oblong, rather densely clothed with very long erect hairs; black, the pronotum with a broad transverse orange band. Head with an impressed median black line, the vertex with a prominent pit on each side above the eyes. Antennæ long, slender, dark fuscous, the basal portion of segment I and all of II and III lighter, the proportional length of the segments:—I:II:III:IV = 45:38:42: 39; segment I moderately stout, distinctly curved, III slenderer than II, IV fusiform. Rostrum stout, apical segment black, surpassing intermediate coxæ.

Pronotum transverse, shallowly and broadly emarginate behind, slightly shorter than metanotum and about two-fifths the length of mesonotum. Mesonotum strongly narrowed posteriorly, truncate behind. Legs yellowish, somewhat tinged with brown, the tarsi black; clothed with dense whitish pile with numerous extremely long yellowish hairs. Connexivum broad. First genital segment deeply emarginate behind, strongly and roundly excavated beneath. Length, 4.14 mm.; width, 1.5 mm.

Holotype, apterous male, Orizaba, Mexico, January 17, in Drake collection. *Paratypes*, 2 males, taken with type. The female and the winged form are unknown.

Aside from the other structures, the larger size, extremely long hairs clothing body and legs, and the structure of antennæ and thorax separate this species from its congeners. It has somewhat the general aspect of a *Rhagovelia*, but belongs to the group of species of *Microvelia* containing *M. americana* Uhler. The hind femora of the male bears along the distal half of the inner surface several spines two or three of which are strongly curved. In the holotype the hind femora are slightly stouter and the spines are shorter than in the paratypes; also in the holotype the spines on the right femora are slightly more developed than those on the left.

Microvelia fontinalis Bueno.

Specimens are at hand from the following localities: OHIO—Berea, July 16, 1914, C. J. Drake. TENNESSEE—Knoxville, June 27, 1891, H. E. Summers. VIRGINIA—near Plummer's Island, Maryland, October 30, 1921, H. S. Barber. IOWA—Burlington, August 4, 1926, H. M. Harris. COLORADO—Wray, August 4, 1925, C. J. Drake.

This species has heretofore been recorded in literature from Ohio, New York, New Jersey, Indiana and Michigan. One of the Tennessee specimens is winged, this form previously being unknown. (*Morphotype*, in the collection of H. E. Summers at Iowa State College.)

Macropterous form: Brownish fuscous with two elongate white spots at base of elytra, the pronotum with a transverse orange or fulvous stripe in front. Pronotum strongly developed, coarsely pitted, carinate down the middle, the apex broad and sub-truncate; humeri large and prominent. Hemelytra extending to tip of abdomen, dark brown with two of the cells beyond the basal spots tending to become more or less whitish. Length 2.5 mm.; width, .93 mm.

Microvelia hinei Drake.

Originally described from Ohio, *M. hinei* has since been recorded from New York, Massachusetts, Michigan, and Florida. The authors possess specimens from the following additional localities: ARKANSAS—Little Rock, August 30, 1926, H. M. Harris. MISSISSIPPI—Charleston, Crowder, Fayette, McComb, Ocean Springs and Woodville, various dates (C. J. Drake and H. M. Harris). DISTRICT COLUMBIA—Washington, August 13, 1889, O. Heidemann, and December 30, 1915, W. L. McAtee. IOWA—Wapello, August 16, 1926, H. M. Harris.

Microvelia borealis Bueno.

Heretofore known from Maine, New York, New Jersey, Connecticut, Massachusetts, Indiana, Michigan, Illinois and Kansas. To these may be added the following additional localities: OHIO—Lake Pippin, Sugar Grove, Rock Bridge, Delaware, and Columbus, June-August, 1916, C. J. Drake. IOWA—Ames, Wall Lake, Burlington, and Farragut, summers of 1924-1927, C. J. Drake and H. M. Harris. MISSISSIPPI—Port Gibson, Vicksburg, and Woodville, July, 1921, C. J. Drake; Charleston, and Crowder, August, 1925, H. M. Harris. FLORIDA—Gainesville, June 9, 1918, C. J. Drake. NEBRASKA—Fremont, August 30, 1925, C. J. Drake. OREGON—Corvallis, June 30, 1926, C. J. Drake. CANADA—Ottawa, Quebec, September 7, 1890.

Microvelia austrina Bueno.

Described from Raleigh, N. C., and heretofore known only from there. Specimens are at hand from: MISSISSIPPI—Charleston, September 7, 1925, H. M. Harris; and TENNESSEE—Knoxville, June-July, 1891, H. E. Summers. Many of the Tennessee specimens are winged. (*Morphotypes* in the Summers' collection at Iowa State College).

Macropterous form: Pronotum strongly developed, dark brown with a large transverse fulvous spot in front, coarsely pitted, the humeri very prominent. Hemelytra extending to tip of abdomen, dark brown, the veins fairly distinct. Length, 1.92-2.14 mm.; width, .61-.64 mm.

Hydrometra martini Kirkaldy.

OHIO—Columbus, Tiffin, Malta, Prentice, and Zanesville, July-August, 1916, C. J. Drake. FLORIDA—Gainesville, July 7, 1918, C. J. Drake. MISSISSIPPI—Port Gibson, Agr. College, Woodville, and McComb, July, 1921, C. J. Drake; Charleston, September 7, 1925, H. M. Harris. NEW YORK—Ithaca, August 7, 1895. OREGON—Corvallis, June 26, 1926, C. J. Drake. This species has heretofor been doubtfully recorded from the Pacific Slope. More than a hundred specimens were taken in a swamp at Corvallis, Oregon.

THE GENERAL COURSE OF EVOLUTION IN THE PLANT KINGDOM.*

STUDIES IN DETERMINATE EVOLUTION, I.

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A study of the system of plant relationships inevitably leads to a consideration of the processes through which the system came into existence. Having spent many years in an attempt to learn something of the true phyletic relationships of plants, the writer desires to present, in a series of short papers, some of the remarkable phenomena which have come to light and which apparently have never been published heretofore in any adequate manner. These papers will bear the subtitle, "Studies in Determinate Evolution," so that they can easily be recognized as forming a part of a general presentation. The term, "Determinate Evolution" is used advisedly as expressing the actual condition of things in all evolutionary movements of a fundamental nature. All such primary movements attain a definite limit, sooner or later, beyond which no further movement in the given direction is possible. This broad generalization will be justified when some of the more important evidence has been submitted. All of the more fundamental taxonomic forms, therefore, fall into what will be called orthogenetic series, and these series are the result of progressive and perfective movements, which commonly are profoundly consistent in their development.

In general, evolutionary movements are either segregative or progressive. But the segregative mutations are determinative as well as the progressive mutations. Each segregative

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movement produces narrower limits within which further mutations are confined. Thus when class, order, family, or genus limits are once established all further movements are within the limits thus set up. It is this fact, together with the general principal of irreversibility, that is responsible for the taxonomic system of larger and smaller phyla. Furthermore, the different movements which may take place in an organism are largely independent of each other. There is a certain correlation of a general sort, nevertheless fundamental evolutions, as for example that of the flower, are not at all dependent on any special type of structure or function, nor on any definite degree of advancement in the series, nor on any special geological period or climatic cycle. The property or potentiality responsible for the development of flowers appears independently a large number of times at entirely different levels. Another important development which will make this principle evident is the evolution of the time of sex determination from the bisporangiate flower condition to the monecious and diecious conditions. This movement has taken place independently a very great number of times in the most diverse morphological systems and at every level of advancement from the very low gymnosperms to the very highest dicotyls. The more primitive movement of sex evolution in the gametophyte has proceeded in the same manner. The two evolutionary movements given above are characteristic of a very large number of cases which it is the intention to present as occasion permits.

As intimated, there is no correspondence between the general evolutionary movements and the environment. Evolution, from the beginning, has ploughed its way consistently through the environment. Evolution is kinetic and not static. It is progressive and orthogenetic; it is perfective and, as stated above, determinative. The movements in general have no special utilitarian import. The two older prominent hypotheses of evolution, namely Lamarck's utilitarian explanation on the basis of desires and of use and disuse, and Darwin's utilitarian selection are purely static conceptions and do not at all correspond to the actual systems of taxonomy which they are supposed to explain. Utilitarian and selective theories are anarchistic, depending on the circumstances or accident of the environment to bring about a movement. They are reasoning in a circle and a contradiction of the taxonomic system as it is actually evolved. If either Lamarckism or Darwinism were

true, we would have a fundamentally different taxonomic system and this system would be in harmony with the environment but would nevertheless be anarchistic if considered by itself, since the habitat itself is continually changing. If the changing habitat were the cause either of a direct utilitarian, evolutionary response or of a selective value, the organisms which had developed in it at a given time or had taken refuge in it in the first place would be subject to these cyclic changes and an anarchistic system would be the result. But nothing of the kind is present in the plant world. On the contrary there is a most remarkable cosmos. These older evolutionary hypotheses belong to the kindergarten period of causative biological science and are purely teleological in their implications. Evolution goes on without any reference to special teleological ends, except that we can say that the system developed has a general utility and fits into the environment in which it has taken place to a greater or less degree. Philosophically there is no contradiction but rather a confirmation of the principle of universal design. It is the principle of special design, or special teleological causation, that finds no basis of support in the taxonomic system. There is a general utility and a universal design plainly in evidence. The whole system does work admirably and has been successful for millions of years. But this universal principle of utility is something very different from the notions of special advantages and special utilities on which the older static theories are developed. Since any organism cannot be dissociated from an environment of some kind, the principle of general utility is always in evidence. But the same orthogenetic movements have taken place in environments diametrically opposite in nature, as for example, many exactly parallel movements of angiosperms into the water, on the one hand, and into mesophytic and xerophytic conditions, on the other. In the angiosperms as well as in many other groups, there is a profusion of parallelisms, yet since evolution is determinate, a species or a larger group of any kind when once lost can never be replaced or duplicated. This is the conclusive testimony of paleontology.

Leaving the consideration of the taxonomic system and its non-correspondence with environment, we find, nevertheless, that there is an abundance of ecological adaptation in details of form and function, but these ecological characters, in general, do not run parallel with the taxonomic system. And since the

taxonomic movements are known to be independent of specific environments, the ecological adaptations, because of a lack of evidence to the contrary, must be considered to be brought about in the same general way, namely, through intrinsic changes which take place in many environments but which are occasionally of such a nature that the environment exercises a decisive eliminative effect. This must be the scientific inference in regard to ecological adaptations until acquired characters can be shown to be induced in the phylogenetic line as readily as they are induced in the ontogentic cycle. Instead of having natural selection in the old sense of the term, we have natural or selective elimination. But this elimination is to be considered as operative only in very special physiological and morphological developments. The vast majority of forms, structures, and functions have an agreeable survival value in the same general environment. The same general environment, for example, will harbor members of the plant kingdom from one end of the series to the other as well as a miscellaneous assemblage of animals. Furthermore, structures of exactly opposite nature in homologous parts survive in the same environment, and sometimes these structures may have a fanciful utility and sometimes not. As stated before, evolution has been described as irreversible and this is true for all fundamental movements. It is only in the extremely minor details that reversibility seems possible and this, as the paleontological record shows, has never involved any of the general movements of the organism, whether plant or animal. It must be emphasized that, in a general sense, evolution is non-selective and non-utilitarian. Very frequently a utility evolves that is of absolutely no value to the possessor, when compared with a lower, related form that has not evolved the utility; and since evolution is orthogenetic and determinative, there are frequently also developments which pass far beyond the limits of practical utility to the realm of the so-called over-adaptations. In some cases also, the development is a positive disadvantage to the possessor.

Evolution and the taxonomic system which comes from it are, therefore, anything but anarchistic systems. Those who hold to an anarchistic system of philosophy, whether political or scientific, need not look for support of their views from a study of the phyletic taxonomic system found in the plant kingdom.

The first part of the problem of evolution is to find out exactly what the process is and what has been the result of its operation, and after we have discovered some of these things we may proceed to investigate the causes of the process. In the past, evolutionary science so-called has commonly proceeded in the opposite direction. A dogmatic hypothesis was formulated, based on some preconceived philosophical attitude and then isolated facts were assembled which appeared to give a plausable proof of the assumption. This procedure is not science and has in the past resulted in enormous reversals and repudiation of widely accepted theories. True inducive science demands that theory shall follow a certain foundation of ascertained phenomena. It also demands that there be no confusion of fact and assumption and that reasoning in a circle shall be tabood.

THE EVOLUTION OF THE GENERAL SERIES.

Without going into the question of the origin of the protoplast, which would take us too far afield, we. will begin with a consideration of the general nature of the lowest known organisms. These organisms have a definite protoplast or a definite unitary cell organization. Whatever its origin, the cell is established as the unit of the living reaction system. Life phenomena are manifested by cells. Thus the organized cell is the starting point and the basis on which a complicated reaction system is built up, proceeding step by step from the lowest to the highest stage attained in the evolutions of organisms. The building up or evolving of the fundamental reaction system has been attained by adding at each stage some new potentiality or potentialities which were not there before. The new fundamental properties are laid down on top of the old. The old is not destroyed nor even inhibited but the new simply makes the reaction system more complex. This general evolution is, therefore, also to be regarded as an orthogenetic progression, although this may not be so manifest at first thought as some of the remarkable movements which take place in some of the greater or smaller phyla. When one remembers, however, that these new properties are commonly introduced not simply in one line but into all the advancing lines, then. their evolution becomes the most profoundly remarkable of all the serial, orthogenetic movements known.

In the lowest plants, the cell is not nearly so elaborately organized as it becomes a little farther up the scale. These lowest plants are properly called PROTOPHYTA and the very lowest are apparently the group of the *holophytic bacteria*. There is no sex potentiality but the general properties manifest are: (1) unitary nature and activity of the protoplast, (2) assimilative property or hereditary perpetuation of the system, (3) division of the protoplasts or cells, and (4) separation of the units after division. These properties are present in all higher organisms also but the separation of cells becomes greatly restricted. They are the first and fundamental potentialities of all living things whether plant or animal. There are a number of important physiological systems established which are of a segregative character as various types of metabolism resulting in holophytic, saprophytic and parasitic groups, flagellate and non-flagellate, chlorophyll-bearing and chlorophylless groups, etc. This subkingdom, therefore, represents in itself a great period of evolution.

THE FIRST GREAT TRANSITION.

In passing from the lowest to the higher organisms, both animal and plant, we find that there are three fundamental and universal advances. (1) The development of the colony or multicellular condition, brought about by a delay and usually a restriction of the process of cell separation after division; (2) The development of the process of differentiation of cells and tissues in the body, and (3) the development of the sex-potentiality. For purposes of a definite taxonomy it becomes necessary to choose one of these three—multicellular condition, differentiation process, or sexuality—as a basis of segregation, since the appearance of the three characteristics are not coincident in the various primitive groups. The most suitable and definitely determinable characteristic is the sex-potentiality. Therefore, the Protophyta are made to include all the plants which are nonsexual as contrasted with those having sexuality, namely the METAPHYTA. As stated, some Protophyta are multicellular and differentiated while some of the lowest Metaphyta are unicellular or are undifferentiated. However, the evolution soon proceeds far enough that shortly all organisms, whether plant or animal, possess the three added characteristics, namely, multicellular condition, differentiation,

and sexuality.   All the higher Metaphyta and all the Metazoa therefore possess the seven characteristics mentioned thus far.

With the evolution of the sex-potentiality there are possible, from time to time, three general states in the cell lineage: (1) the female state, (2) the neutral state, and (3) the male state. In some plants the neutral state is the prevailing condition in others the neutral condition may be rare or never properly developed.   With the advent of sexuality also there is an entirely new mode of hereditary transmission.   The two fundamental features are primary sexualization of the haploid gametes, resulting in fertilization, and primary sexualization of the chromosome sets in the diploid reproductive phase, resulting in the reduction division.   These processes are responsible for Mendelian segregation of heredity and Mendelian interaction of dominant and recessive allelomorphs in the diploid cell. These new phenomena are also characteristic of all the higher plants and animals.

PROGRESS IN THE SECOND SUBKINGDOM.

The NEMATOPHYTA show the progressive acquirement of a number of very important general properties among which the most important are: (1) the attainment of dimorphic gametes, and (2) the evolution of secondary sexual states and characters. It is needless to say that these advances are universal when once attained and are shared also by the animals.   The appearance of secondary sexual characters is brought about by a shifting back of the time of sex determination into an earlier stage of the ontogeny before gametogenesis.   These secondary sexual states give rise to dimorphisms by influencing hereditary expression but the cells do not manifest the attractive properties which appear later in the gametes.   Thus the higher plants have a five-fold manifestation of the sex-potentiality in the cell lineage: (1) neutral state, (2) secondary female state, (3) primary female state, (4) secondary male state, (5) primary male state.

TRANSITION TO THE METATHALLOPHYTA.

The transition from the THALLOPHYTA to the METATHALLO-PHYTA represents the greatest break or hiatus in the plant series.   The Metathallophyta are a monophylletic group when compared with the lower forms.   There was a long period of

evolutionary advancement in which the ancestors of the group developed all the fundamental characteristics outlined above for the Thallophyta and in addition the Metathallophyta evolved a characteristic life cycle. All of the higher plants have a uniform type of life cycle namely, the typical, antithetic alternation of generations with a haploid gametophyte and a diploid parasitic sporophyte. In this cycle there are twelve characteristic stages. These stages are retained to the end of the plant series. In the Thallophyta there are several types of alternation of generations but none that corresponds to the typical antithetic cycle of the higher plants. In most cases the sporophyte is an independent plant, like the gametophyte. The nearest approach is in the red algæ where the zygote undergoes vegetative growth and produces a number of carpospores which are discharged and develop the independent sporophyte. The twelve stages of the typical antithetic alternation of generations cycle are as follows: (1) Haploid gametophyte, (2) dimorphic gametangia, (3) dimorphic gametes, (4) fertilization, (5) oospore or zygote, (6) germination in the ovary, (7) diploid sporophyte, completely parasitic or parasitic in its embryonic stage only; (8) sporangium, (9) sporocyte, (10) reduction division, (11) tetraspores, (12) germination.

BRYOPHYTE STAGE.

This transition leads up to the third subkingdom, or general evolutionary stage, called the BRYOPHYTA. The parasitism of the sporophyte is complete. The sporophyte is also completely determinate in its growth, since the production of its spores either involves the entire individual or its single terminal growing axis. Only in one group is there a peculiar type of intercalated indeterminate growth evolved and this is usually of short duration. There is a marked progression in the size and importance of the sporophyte as compared with the gametophyte, and in general this forward movement in the evolution of the sporophyte persists to the very summit of the plant kingdom. The sporophyte is entirely neutral, the sex potentiality never giving rise to sexual states in the normal conditions. The lowest species have a sporophyte that is nothing but a sporangium, representing a hollow sack of spores; the highest species have a fairly well organized body with foot, stalk,

photosynthetic organ with stomata (hypophysis), and sporangium, and in the Anthocerotæ, as intimated above, even a crude beginning of indeterminate growth. One of the most important progressions is in the continually smaller area of tissue involved in the spore reproductive process. In the lowest species the entire individual except the epidermal layer is transformed into spores; in the higher liverworts there is sterile tissue interspersed with the spores in the sporangium; while in the very highest the central part of the axis remains vegetative, thus shifting the reproductive process to the outer regions of the stem. This is of most profound significance from an evolutionary point of view as will appear below.

TRANSITION TO THE VASCULAR PLANTS.

The transition to the vascular plants is accomplished by the addition of heredity which causes a shifting of the reproductive process of the sporophyte from the terminal bud (cauline sporangia) over to the newly evolved lateral appendages of the stem, or the leaves, thus giving rise to sporophylls which with some modifications are characteristic of all vascular plants. The growing axis is now an indeterminate system. Thus the transition from bryophyte to homosporous pteridophyte is a change from a determinate sporophyte to an indeterminate sporophyte, and this leads over to a two-phased condition, the first phase of the sporophyte being parasitic and the later phase entirely independent. This two-phased life of the sporophyte, thus evolved, is characteristic of all higher plants. It is again a fundamental characteristic imposed on the one-phased condition of the bryophyte type of sporophyte. Of course, the whole morphological condition advances in complexity by the appearance in the sporophyte of potentialities for the development of a vascular system, leaves and roots. As stated above, the shifting of the point of spore production from the stem axis to a lateral appendage of the stem is not a sudden advance but shows in itself a definite orthogenetic advancement. It is evident that this shifting of the reproductive center from the region of the stem axis was well advanced before the appearance of a definite vascular system, so that with the appearance of lateral appendages the final step to sporophylly was but the culmination of a movement begun far down in the bryophyte stage.

Whether the lowest vascular plants originally produced nothing but sporophylls or whether from the beginning they developed alternating zones of foliage leaves and sporophylls is of no great consequence, and can probably never be proven one way or the other. Our living primitive vascular plants apparently all have such alternating zones. One thing is certain. The vascular plants did not originate from a strobilus-like sporophytic ancestor. The flower is a secondary determinate system evolved later from or in the earlier indeterminate system. The shifting of the point of spore production from the terminal bud to the lateral stem appendages was the primary condition for the development of indeterminateness. Now in the higher plants the lateral shifting of the reproductive function progresses still farther to the lateral organs of secondary axes as in cycads like *Macrozamia* where the cones are always lateral organs. In *Equisetum* and many conifers like spruces, firs, pines, etc., the terminal buds of all primary axes remain entirely vegetative and the flowers are developed on secondary or tertiary axes or on axes still more remote from the primary.

IMPORTANT ACQUISITIONS IN THE STAGE OF THE PTERIDOPHYTA HOMOSPORÆ.

Among the progressive movements developed in the homosporous pteridophytes is the evolution of dimorphism between foliage leaf and sporophyll. This condition is established in this fourth subkingdom and becomes more intense or extreme, in general, the farther one proceeds along the line of any of the higher phyla. The development of the flower or determinate, sporophyll-bearing axis, is also attained in some lines of homosporous pteridophytes and becomes characteristic and more pronounced and extreme as one reaches the highest phyla. The advancement in this respect is extremely definite and extremely orthogenetic. As in many of the bryophytes, some of the highest species have also shifted the time of sex determination in the gametophyte back in the ontogeny to the spore itself so that the gametophytes become unisexual.

TRANSITION TO THE HETEROSPOROUS PLANTS.

The transition between the fourth and fifth subkingdoms is again a fundamental one involving a definite condition of sexuality. It was just as important for the origin of the

peculiarities of the higher plants as the origin of sex itself was at the first transition in giving rise to a new type of hereditary phenomenon. In this transition a new potentiality is introduced which causes the time of sex determination to be shifted backward in the life cycle from the beginning of the gametophyte to the end of the sporophyte, from which point it proceeds in many groups back to the beginning of the sporophyte. This step was probably necessary for the evolution of any kind of seed habit. All the main lines of pteridophytes and, of course, all the lines that evolved the seed habit later took this extraordinary evolutionary step. It was a new potentiality which determines functional states or gradients of a certain type in the diploid sporophyte and these in turn cause secondary sexual states to arise. In the sporophytes of bryophytes and homosporous pteridophytes no such states appear normally although the cells have the sex potentiality. Thus the new heredity gives rise to trimorphisms and dimorphisms in the sporophyte, while as stated all sporophytes below, whether bryophytes or homosporous pteridophytes are normally homomorphic in respect to sex because they remain in a neutral state. The secondary sexual states which arise determine the character of the reduction spores and thus the sexual states of the gametophytes are pre-determined. All gametophytes of heterosporous plants are unisexual while those of the homosporous, whether bryophytes or pteridophytes, are more commonly hermaphroditic. Along with the development of secondary sexual states in the reduction spores goes the great reduction in size and importance of the gametophyte generation, especially the male gametophyte. This latter condition paves the way for the evolution to the seed habit. The orthogenetic and progressive character of this great movement, as well as the intrinsic nature of the evolutionary process, are clearly in evidence when one considers the numerous independent appearances of the condition.

TRANSITION TO THE SEED PLANTS.

As stated, the development of PTERIDOPHYTA HETEROSPORÆ, through the shifting of the time of sex determination, was a necessary step for the development of the fifth transition. This evolution adds a number of fundamental properties to the system, and a large number of almost simultaneous move-

ments take place which make the history of the transition to
the seed plant condition appear almost like a fairy tale.   The
great central movement in this transition was the retention
in the mature sporangium of the spores giving rise to the
development of the parasitism of the gametophytes.   This
condition imposed upon the fundamental complex of properties
already attained was a truly marvelous step in advance.   The
reduction spores are now in the same evolutionary stage as the
zygote was from the liverworts on up.   The female gametophyte
is permanently parasitic and enclosed in the megasporangium
(ovule).   Thus the development of the parasitic relation be-
tween the two generations has reached the final limit possible.
The telescoping has advanced as far as the conditions of life
will permit.   The orthogenetic movement of one generation
depending on the other has reached its ultimate possibility.   It is
as though a short snake swallowed a long snake's tail and then
the long snake turned around and swallowed the short snake
along with its own tail.   The seed of the GYMNOSPERMÆ is thus
a triple organism representing two generations and a part of a
third.   The male gametophyte acquires a double-phased life.
At first it is parasitic in the microsporangium and later it is
parasitic in the ovule through the development of the pollen-
tube.   This two-phased condition is again carried through the
last subkingdom, the ANGIOSPERMÆ.   A remarkable addition is
also made to the previous complement of fundamental poten-
tialities of the sporophyte.   The sporophyte is still a two-
phased individual but with the intercalation of a resting con-
dition or a greater or less degree of dormancy between the two
phases.   Several additional minor details of complexity are
added at the fifth evolutionary transition to the hereditary
equipment of the plant which need not be mentioned here.
One however is very interesting.   The parasitic sporophyte
individual in the seed, which becomes the plant to struggle with
the outer world is now protected to the extreme and supplied
with food for use after its reawakening, by means of which it
can establish itself promptly as an independent organism when
opportunity is afforded.   The higher plants no less than
practically all the higher animals have taken their offspring out
of the struggle for existence with the external world, and have
provided a most advantageous condition of opportunity for
survival and also for a favorable migration from the parent
habitat.   At the level of seed evolution nearly all phyletic

lines have also attained to the complexity of determinate reproductive shoots or flowers, only two of the lowest living genera of gymnosperms being flowerless, namely, the carpellate plant of the species of *Cycas* and both carpellate and staminate plants of *Ginkgo*. The acquisition of the flower is another striking example of multiple progressive movements attained in all but a few of the main lines of vascular plants. When once attained also the flower has never devoluted, although in the lower types proliferation, as one would expect from the establishment of any such fundamental potentiality, is common.

TRANSITION TO THE ANGIOSPERMÆ.

The sixth transition leads to the highest subkingdom, the present culmination, and probably the final one, in the fundamental progressive evolution of the plant kingdom. The important change is the closing of the megasporophyll around the ovules which necessitates the acquisition of a new organ of pollination, the stigma. The closing of the sporophyll was accomplished in some lines of ferns but, of course, no stigma is present in these. The presence of a stigma and closed ovulary in the carpel requires an additional development of the pollen-tube. The pollengrain now germinates, not in the micropyle of the ovule as heretofore, but on the stigma. Thus the pollen-tube has an extensive growth before it enters the micropyle or some other part of the ovule. The angiosperms also attain the limit in many lines of determinate, floral development in the epigynous condition and in the extreme development of zygomorphy. The first mentioned condition never being attained in any lower plants and the second only to a very slight degree.

Another, and really the most profound of the added potentialities in the evolution of the Angiospermæ is the process of triple (or sometimes multiple) fusion of two cells of the female gametophyte with a sperm to form the triploid, definitive nucleus from which a distinct generation, the endosperm or xeniophyte, develops. This process makes the life cycle and the genetics of the angiosperms much more complicated than those of any other organism, either plant or animal. The seed now contains structures representing four distinct generations, two diploid generations, a haploid generation, and a triploid or sometimes a polyploid generation.

THE ARRESTED LIMITS OF THE EVOLUTIONARY PROCESS.

There is another fundamental fact which stands out and demands solution which is just as remarkable as the evolutionary progression itself. Why did the various groups of plants remain on the several levels which they have attained? There is a principle of stability involved which makes living organisms the most enduring things that we know of. There is also no evidence that any of the members of any level will ever evolve beyond the general limits to which they have attained. There may be endless evolutions in a subordinate way but the whole taxonomic system and the whole paleontological history indicate that the general process has been accomplished. It is also very doubtful whether any very great advance could be possible out of the angiosperm condition which might give an eighth subkingdom of plants. All the fundamental possibilities, as complexity of life cycle, evolution of the time of sex determination, reproductive system, interactionary parasitism, limit of floral evolution, etc., seem to have reached the limit of possible fundamental advancement of the system. Paleontology and a study of the present taxonomic system is a sufficient answer to any such fantastic speculation. So all we can say at the present in answer as to why a bacterium never got beyond the nonsexual unicellular stage, why a *Platanus* or a *Sassafras* of the present day is the same as a *Platanus* or a *Sassafras* of the time of the beginning of the Cretaceous period, why a liverwort or a moss never got beyond the liverwort or moss condition while other things at the same time were advancing in a most remarkable manner, is that in all such cases something appeared in the system which apparently forever prohibited a mutative change in the given direction, forever inhibited the addition of the essential potentiality into the given protoplast. As stated, this problem is just as fundamental and demands just as much attention and investigation as the actual evolutionary advancement and change itself.

CONCLUSION.

Now anyone who will take the trouble to understand what the entire evolutionary process outlined above implies will readily see that we are dealing with a kinetic principle, with a principle of progressive and perfective movement, with a most

remarkable accumulative or building up process, with a system which proceeds in the same general way in many diverse morphological and physiological complexes, right through the diversity of environments which are now on the Earth or which have existed in past geological ages. It is also clearly evident to any one, who knows something about the taxonomic system of plants and the geological history of organisms, that the progressive movements, like the evolution of the flowers in the various phyla, for example, have not at all taken place at the same time but often in entirely different geological horizons. When one comprehends all of this, then it becomes evident that much of the speculation of the nature and cause of evolution, developed in the past and still held to a considerable extent in the present, are, to repeat the proposition stated in the introductory part of this paper, to be regarded as amateurish beliefs mostly supported by the common illogical devise of reasoning in a circle, from which biological science should have been freed long ago. In this category are to be placed such teleological hypotheses like Lamarack's use and disuse through the sudden acquirement of new desires, Darwin's natural selection, sexual selection, and selective mimicry, and especially all the teleological vagaries of the Neo-Darwinians, as well as the unsupported belief in a direct specific causal effect of environment and in the inheritance of acquired characters.

The general array of facts and phenomena presented in the outline of the general fundamental evolutionary movements thus indicate that: Evolution is intrinsic, kinetic, progressive, orthogenetic, perfective, and determinative.

DEMONSTRATION OF THE LIFTING POWER OF EVAPORATION.

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The lifting power of evaporation and the liquid tension present in water are two important forces in the transpiration stream. The desirability of having a better conception of these forces has led to numerous experiments. A modified Askenasy experiment has proven quite successful in demonstrating these forces in moving materials. A clearer picture can thus be impressed upon the minds of students in botany by actual demonstration.

An attempt was made first to perform the experiment using such materials as are usually available in a general botany laboratory and second to make the demonstration less cumbersome and more successful. The results obtained with the apparatus described in this paper have shown that with a relative degree of precaution, these two forces can be demonstrated in every laboratory.

Askenasy in 1896 fused a glass funnel on the upper end of a long glass tube. A layer of plaster of Paris was placed in the broad upper end of the funnel. After the plaster hardened the apparatus was filled with water and the end of the glass tube dipped in mercury. As the water evaporated from the plaster surface the mercury rose in the tube and attained a height of 82 cm. Ursprung (1913) used a porous porcelain cylinder as an evaporating surface. He improved considerably upon the technique and obtained much better results. However the demonstration was still quite unwieldy. A great improvement in the set up of the apparatus, as worked out by Lubin, is included in Livingston's 3rd edition of Palladin's Plant Physiology (1926).

The apparatus used in these experiments was essentially the same as Lubin's arrangement, and with the few improvements made, is shown in the diagram (Fig. 1). The materials needed for the apparatus are: a porous porcelain cylinder or cup, a long J-shaped, thick walled, small bore glass tube, a bottle containing mercury, a large beaker, a source of heat such as a Bunsen burner, a vacuum pump and a one-hole and a two-hole rubber stopper.

In preparation for a demonstration, the apparatus was first thoroughly cleaned. The porous porcelain cylinder or cup (C) was filled with distilled water and attached by means of the one hole rubber stopper (D) to the short arm of the J-shaped vertical glass tube (E). The porcelain cylinder was then submerged in a beaker of water. The end of the long arm of the glass tube was fastened into the bottle containing the mercury by means of the two-hole rubber stopper (H) so that the end of the tube dipped below the surface of the mercury. The attachment for the suction pump (G) was fitted into the second hole of the rubber stopper.

After the apparatus had been assembled the water in the beaker was heated to boiling and by applying suction to the long arm of the J-shaped tube the hot water was caused to filter through the system. After the apparatus had been thoroughly washed and all undissolved air had been driven from the system by boiling it was allowed to cool to room temperature. By allowing the apparatus to stand, dissolved air could penetrate the entire system. Consequently tension was shown in water solutions containing dissolved air which no doubt is the condition of the water contained in the plant vessels and tissues. With the apparatus set in this manner, however, liquid tension could not be obtained. It was found necessary to substitute a colloidal coat for the evaporating surface of the porcelain cup. The coating used was a colloid such as agar agar or gelatin.

A colloid coat has two advantages: 1. A colloidal gel can be more easily duplicated than a porcelain surface and by coating several cylinders with the same colloidal gel, one can be sure of having relatively uniform evaporating surfaces on several cups. 2. Coating eliminates the difficulty encountered by former workers in finding porous porcelain cylinders that were sufficiently fine pored to support the air water menisci against several atmospheres of pressure. Some of the colloidal coats tend to
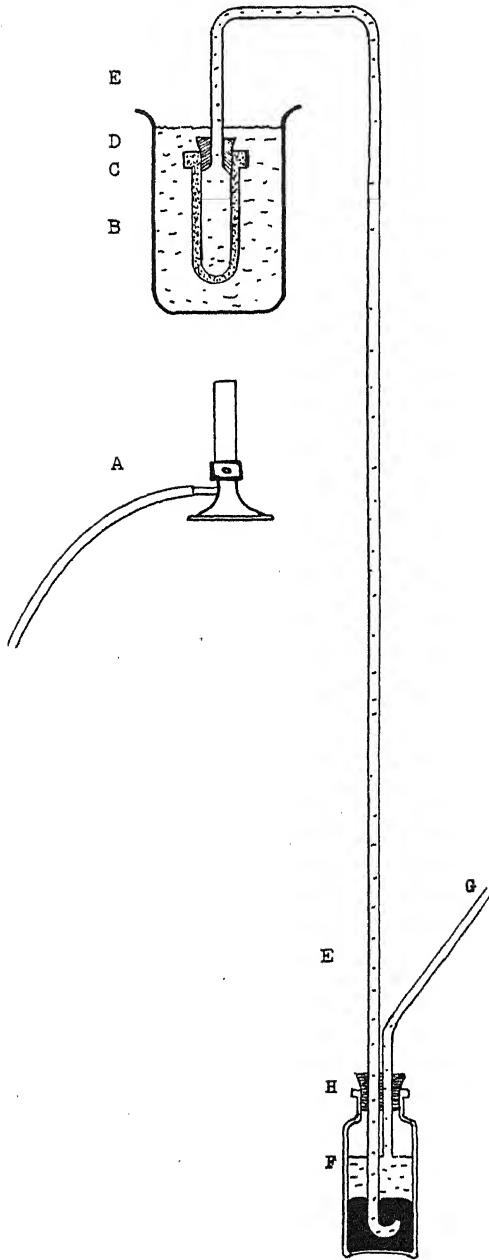
FIGURE 1

deteriorate or wash off when the cylinder is submerged in the beaker of water. A discussion of the characteristics of the various types of coats used will be included with the results.

The general method of applying the coat was as follows: the beaker was removed from around the porous cup and immediately 100 to 150 c.c. of the colloidal sol was poured over the rubber stopper and porous cup. Care was taken to see that the entire cup surface has been covered by the colloidal sol. A sufficient amount of the sol adhered to the cup to form an evaporation surface. When collodion (dissolved in alcohol and ether) was used as the colloidal sol it was found necessary to first wipe off all excess water from the surface of the cup.

The suction pump should be detached before allowing evaporation to take place. The evaporation of the water from the cup caused a decrease of water volume and this decrease of volume was compensated by the drawing of the mercury up into the glass tube. This process continued until a break occurred somewhere in the water or mercury column. Most of the breaks occurred in the water column. As soon as a break or bubble occurred the level of the mercury, if it was above atmospheric pressure, dropped to a level corresponding to nearly atmospheric pressure.

All that was necessary for a second trial was to submerge the porous cup in the beaker of water and the infiltrating water would force the bubble from the system. Applying suction to the long arm of the glass tube hastened the process. Cutting the lower surface of the one-hole rubber stopper so that it tapers toward the glass tube and bending the tip of the long arm of the glass tube, as shown in the diagram, often aided greatly in the removal of bubbles. After the bubble was removed, the suction pump was detached and the porous cup exposed to the air. Air currents from an electric fan hastened the evaporation process.

The time required to run a demonstration could be divided into two parts, first the cleaning and boiling of the apparatus and second the running of a trial. An hour of boiling the water in the beaker, simultaneously applying suction, has been found sufficient to remove all undissolved air. The apparatus was then allowed to cool to room temperature. The apparatus may be boiled a day or two previous to a trial, thus saving time. The time required for a trial after the coat has been

applied varied from ten minutes to several hours depending upon the bore of the glass tube, the consistency of the colloidal coat applied, the humidity and movement of the air and the height reached in the trial. Ten to twenty-five minutes were required to attain a height of 100 to 150 cm. in a one m.m. tube when a 20% gelatin coat was used.

The results or heights given have been corrected by the following formula:

$$H = h + c + \frac{W_1 - W_2}{13.6}$$

H = Total height of mercury column.
h = Ht. of mercury meniscus in tube above the mercury level in the bottle.
c = Correction for mercury depression in glass tube.
W_1 = Height of water column from the mercury meniscus to the top of the glass tube.
W_2 = Height of water standing above mercury in bottle.

By subtracting the atmospheric pressure from the total height (H) one has the height in terms of mercury that was supported by the cohesion or liquid tension of the water column.

Gelatin, agar agar, gum arabic, tragacanth, Karo syrup and collodion were used as evaporating surfaces. Sols of the first four were prepared by placing a definite number of grams of the dry granular substance in 100 c.c. of water and then heating to boiling in a water bath. These sols are referred to later as percentage sols. They were applied to the porous cups soon after being removed from the water bath and thus had a temperature of 90–98°C when applied. The Karo syrup and collodion were applied in the commercial form and at room temperature.

The following table gives some of the results. These results, excepting tragacanth, were obtained in glass tubing of 2 m.m. diameter. The trials were all made at room temperature 20 to 25°C.

Sol or Solution	Number of Trials	Average for Trials. Ht. in cm.	Highest Reading	
			Day of Trial	Ht. in cm.
20% Gelatin..........	41	129.1	Dec. 1	188.7
2% Agar Agar.......	22	120.4	Nov. 2	146.1
10% Gum Arabic.....	17	128.9	Nov. 30	168.4
5% Tragacanth...... (1 m. m. tube)	3	120.5	Mar. 7	130.6
Karo Syrup..........	2	111.4	Dec. 6	128.1
Collodion............	6	91.8	Oct. 5	99.2

The sols or solutions were arranged in the table according to their practicability as far as it was possible to determine. A gelatin, agar agar or collodian coat could be used repeatedly as these coats did not wash off when immersed in water. The height efficiency of the collodion, however, placed it at the bottom of the list. Gum arabic, tragacanth and Karo syrup could be used as quite efficient evaporating surfaces for single trials. These coats however wash off when the porous cups were immersed in water in attempting to remove air bubbles from the system.

Gelatin seemed to offer the best type of coat. The following table gives the results obtained from a good 20% gelatin coat.

Cup boiled Nov. 29 (1–3 P. M.)
Cup coated Nov. 29 (8 P. M.)

Time, 1927	Total Ht. cm.	Barometer Ht. cm.	Ht. above Barometer
Nov. 29—8– 9 P. M....	96.6 (Fan)	74	22.6
Nov. 30—2– 3 P. M....	184.4 "	73.5	110.9
Nov. 30—7– 9 P. M....	167.2 "	73.7	93.5
Dec. 1—3– 4 P. M....	188.7 "	75.3	113.4
Dec. 1—7– 9 P. M....	93.6 (No Fan)	75.3	18.3
Dec. 2—2– 4 P. M....	179.8 (Fan)	74.6	105.2
Dec. 3—8– 9 A. M....	144.3 "	75.3	69
Dec. 4—9–10 A. M....	136.5 "	75	61.5
Dec. 5—3– 4 P. M....	132.2 "	74.5	57.7

The four highest records obtained by using gelatin are given in the following table. Data corrected to 25°C.

HEIGHT RECORDS.

Time, 1927	In 2 mm. Tube	Coat of 20% Gelatin	
	Total Ht. cm.	Barometer cm.	Ht. Above Barometer
Nov. 30................	184.4	73.5	110.9
Dec. 1.................	188.7	75.3	113.4
Dec. 2.................	179.8	74.6	105.2
1928	In 1 mm. Tube	Coat of 25% Gelatin Sol	
Mar. 11................	226.6	73.7	152.9

A gelatin coat tended to deteriorate but one coat was generally good for from five to ten trials, provided the trials were made within a week.

SUMMARY.

The above experiments, with an improved Askenasy apparatus may be summarized as follows:

1.   Liquid tension and the lifting power of evaporation can be demonstrated.

2.   A colloidal coat was substituted as the evaporating surface of the porcelain cup.

3.   Gelatin, agar agar, gum arabic, tragacanth, Karo syrup and collodion were used as evaporating surfaces.

4.   With a relative degree of precaution, heights of mercury exceeding atmospheric pressure can be easily attained.

5.   Gelatin seemed to afford the most satisfactory coating. It was easily applied and gave consistently high records. Out of 41 successive trials with 20% gelatin the average total rise of mercury was 129.1 cm. with a minimum of 81.9 cm. and a maximum of 188.7 cm.

6.   The highest record, 226.6 cm., was attained by using a 25% gelatin coat.

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SOME RECENT WORK ON THE STRUCTURE OF THE PLANT CELL WALL.*

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The original researches of Nägeli (26, 27) upon the structure of plant cell walls have stimulated discussion and debate, for more than sixty years. Today the Nägeli theory is still under scrutiny and the issue is by no means settled. The problems of plant cell wall structure are no longer exclusively those of the botanist, but in recent years have aroused the interest of physicists, chemists and even of the mineralogists. Direct microscopic observations have been supplemented with extensive studies under polarized light and with the X-ray. It has been only during the past ten or fifteen years that our knowledge of the physical structure of cell walls has advanced materially, beyond the stage at which Nägeli left it, almost three-quarters of a century ago.

It is the purpose of this paper to summarize briefly some of the recent and important work in this field, and to present a picture of plant cell wall structure as recent research has revealed it. No attempt will be made to review the vast amount of literature on the subject prior to the twentieth century, or even that of the early part of this century. Comprehensive and excellent surveys of this literature can be found in the monograph of Wisselingh (34).

The chemical and physical structure of plant cell walls varies widely in the different plant groups and in the same individual. The walls of the bacterial cells, of the algæ and of the mosses are very different from those of the higher plants. In any individual angiosperm there is an almost equally wide range of variation. The walls of root hairs, of epidermal cells, of woody fibers, of bast cells and of other tissues have but few

characteristics in common. There are, however, two char-
acteristics possessed by most, if not all plant cell walls:

1. Plant cell walls are not chemically homogeneous, but
   are composed of two or more chemically distinct
   substances.
2. Plant cell walls are not physically homogeneous, but
   show stratification, striation and other indications of
   structural variation.

These facts have long been known and have been the
subject of a great deal of study, yet research in the field of cell
wall structure has never been more active or promising than
at the present time.

One of the most interesting contributions to cell wall
research is the work of Hansteen-Cranner (17). This investi-
gator became interested in the toxic effects of Mg, K, and Na
ions toward root growth. When a solution containing only
one of these cations surrounded the root, all growth ceased.
Signs of injury appeared in the region of elongation, i. e., where
cell wall growth was most rapid. Further investigation
revealed that the toxic effect was the result of changes in the cell
wall itself and not the result of injury to the protoplast or
nucleus. In solutions of the injurious cations the cell walls
became swollen and in some cases burst, revealing the naked
protoplast. Mg was most effective, solutions having a con-
centration of 0.0047% were sufficient to prevent root growth
in some cases. Ca, on the other hand, even in solutions of
0.328% produced absolutely no sign of injury. The addition
of Ca to Mg solutions not only prevented injury, but permitted
normal growth.

It was further found that in dilute solutions of Mg, the
roots excreted a cloudy white precipitate. This precipitate
was produced by all roots tested and appeared the same in all
cases. It contained no trace of protein, but consisted largely
of phospholipoids.

In order to determine the origin of this material, the cell
walls were freed from the cell contents, with the greatest
thoroughness and care. The tissue was macerated and
repeatedly washed until microscopic examination showed only
cell wall fragments, and microchemical tests for proteins were
completely negative. These cell wall fragments freed from
every trace of protein material, gave the same precipitate,

indicating that it originates from the cell wall and not from the protoplasm. Hansteen-Cranner therefore concluded that the cell walls in question contained lipoid substances.

Since this original paper, Hansteen-Cranner has greatly extended and amplified his experiments (18, 19, 20), and has conclusively established the fact that the walls of all living plant cells contain relatively large amounts of phosphatides. He has shown that the plasma membranes are also largely, if not entirely, composed of these phosphatides, and that they are in direct and intimate connection with the phosphatides in the cell wall. The plasma membrane is not sharply delimited from the cell wall, but is continuous with the phosphatides that saturate the cell wall. During plasmolysis the plasma membrane does not separate cleanly from the wall, but retains fine thread-like connections with it. This fact, although largely ignored by workers in plasmolytic phenomena, has been previously reported by other investigators (19).

The Ca ion brings about a precipitation of these phosphatides, forming new membranes. The earth alkalies and the mineral acids act in a similar manner. The alkalies and the hydroxides in dilute concentrations act in the opposite way, producing a swelling and a gelatinization of the material. Whenever these ions come into contact with the phosphatides of the cell wall and of the plasma membrane, new membranes are formed—membranes having a widely different character from those normally present.

Hansteen-Cranner has thus demonstrated that the solid cell wall skeleton of cellulose or hemicellulose is permeated with phospholipoids. These phosphatides are not stable compounds, but are easily and extensively modified by changing conditions. Temperature changes, increases or decreases in acidity, the presence or absence of certain ions, and other factors bring about modifications, often extensive modifications, of these phospholipoids in the cell wall and plasma membranes. The formation, for example, of firm insoluble membranes with Ca ions throws much light upon the unfavorable influence that Ca ions exert upon water absorption, and possibly upon the difficulties some plants have in living upon soils rich in Ca. On the other hand, the formation of loose, gelatinous membranes in the presence of K ions may explain the favorable influence of this ion upon water absorption. The fact that phospholipoids bear sugar and probably are the path of sugar

movements from cell to cell, suggests a possible explanation of some of the problems of cell wall growth, or even may explain the idea that the outer layer of the protoplasm (phospholipoid) is itself transformed into cell wall material (1).

Grafe and his co-workers, in a series of papers (13, 14, 15), have confirmed Hansteen-Cranner's work and have carried out extensive investigations upon the chemistry of these phosphatides. From this work it becomes clear that these phosphatides have an important role in cell activities. Not only do the phosphatides determine and control in the large measure the permeability of the cell membranes, but there is also evidence that they and not protein, may form the chromatin of the nucleus and so be related to the whole heredity mechanism.

In a paper published after his death, Hansteen-Cranner (19) went so far as to consider the cell wall alive. Since the wall contains large amounts of phosphatides which are always in intimate union with the outer protoplasmic layers, he thinks that it should be considered a living and physiologically active structure.

This is a view to which few physiologists would subscribe, none-the-less it is an idea that challenges interest. Most botanists have long been accustomed to considering the cell wall as a passive, non-living framework surrounding and supporting the living protoplast. It now appears that no sharp line can be drawn between cell wall and protoplast, but that portions of the latter penetrate more or less completely, the intermicellar spaces of the former. Before the Hansteen-Cranner conception can find general acceptance however, much more must be known about the nature of these phospholipoids, and about their physiological relations with the protoplasm and with the cellulose crystals that form the cell wall skeleton.

Suggestive as this work is, it is the solid skeleton of the cell wall that has attracted the most attention. The physical structure of this framework may be studied in a number of ways:

1. Direct microscopical observation.
2. Microchemically.
3. With polarized light, and with the ultra-violet light.
4. X-ray analysis.

Direct microscopical observation was of course the first method to be used. It revealed the stratification of thick walls and the striation visible on many cell walls. The stratification is more or less distinct in cross section and its visibility varies with the water content of the wall, a fact which has led to the theory that differences in water content *cause* the stratification. The surface markings are of various types: spiral and other striations, cross bands, folds, etc.

The recent work of Aldaba (1) on cell wall structure shows that direct microscopic observation alone, under proper conditions, can give much more information about the structure and development of cell walls than was formerly possible. Aldaba has developed a method of isolating the developing cell intact. This permits a study of the entire cell directly, without resorting to sectioning. Using this method he has shown that some bast fibers are built up of a large number of lamellæ, which seem to arise as a transformation of the outer protoplasmic layer into cell wall material. This observation is of particular interest in connection with the work of Hansteen-Cranner, just discussed.

Microchemical studies have shown the kind, the amount and the location of the different membrane substances in the cell wall. They have shown the chemical changes that occur during the development of the wall, and have furnished a basis for theories of cell wall formation and growth. Wisselingh (34), and more recently Kisser (24), have through the use of microchemical methods shown that cutinized membranes are composed of three distinct lamellæ, an outer layer of pure cutin, an inner layer of pure cellulose, and a middle layer of cutinized cellulose. Wisselingh (34) has also demonstrated that the cork cell wall is likewise composed of three separate lamellæ, an outer layer of strongly lignified cellulose, a thin inner layer of cellulose usually more or less lignified, and between these, a thicker layer of suberin. Anderson (3), also using microchemical methods, has shown that it is possible to separate from one another, the lamellæ composing bast fibers of flax, and to study their structure when so isolated. The same author (4) has applied microchemical methods to a study of collenchyma cell walls and has shown that in such walls there is an alternation of pectic and cellulose lamellæ. The cellulose lamellæ can be separated from the pectic lamellæ and studied separately, for the finer details of their structure. Howe (23),

working on root hairs microchemically, finds a layer of pectic material and a layer of callose forming the wall. Wisselingh (33), Tiffany (32), and Wurdack (35), have shown that the cell walls of various green algæ are also composed of distinct lamellæ, containing one or more different chemical substances. Klein (25) has investigated the cell walls of some blue-green algæ and found them composed of lamellæ, in which the different cell wall constituents were more or less intermingled with one another. Bunning (7) and Shaw (30), found that this type of cell wall structure is present in the Sphagnaceæ and in the fruit coats of *Nelumbo lutea* respectively.

The papers here cited are sufficient to make clear the contribution that microchemistry is making toward solving the problems of cell wall structure. Microchemical studies of the plant cell wall have revealed it as a complex structure composed of distinct lamellæ, the lamellæ in turn being composed of one or more different chemical substances.

The units of cell wall structure, however, are submicroscopic and consequently must be studied in some other way. Most of our information about the fundamental units of cell wall structure has been derived from studies with polarized light and the X-ray.

Cellulose is doubly refractive and this double refraction supplies information regarding the finer details of its structure. As a result of his studies with polarized light, Nägeli considered the cellulose wall as being composed of submicroscopic crystalline micellæ that were definitely arranged in lamellæ. He believed each micellar unit to be surrounded normally with a film of water, and so separated from one another. The stratification visible in cross-section was explained by assuming that the micellæ were of different size and so adsorbed different amounts of water. As the water content of the wall decreased, the micellæ would approach one another, and the stratification would be less apparent. In completely dry cell walls the micellæ would be in direct contact and no stratification would be seen. Microscopical observations showed that the stratification actually does disappear as the wall is dried.

To account for the unequal swelling of cell wall in different directions (i. e., along the longitudinal, tangential and radial axes), Nägeli assumed that the micellæ were elongated. Cubical micellæ would adsorb water equally on all sides and so produce uniform swelling. Cellulose cell walls, however, do not swell

uniformly, but much more in the radial and tangential directions than in the longitudinal. If the units were elongated and arranged parallel to one another in the wall, the amounts of water adsorbed will not be equal on all sides, and therefore the resulting swelling must also be unequal, (Fig. 1).

This theory of water films apparently received support from the results of X-ray investigations which showed that when swelling took place the micellar units themselves did not increase in size, but merely altered their distance relations with one another (31).

Forsaith (9) has suggested an interesting modification of the Nägeli theory to account for the observed behavior of different woods. The checks and fiber ruptures in wood indicate a spiral structure in the cell wall, while the fracture
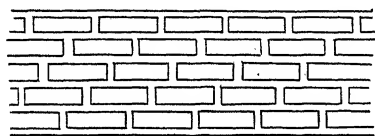
Fig. 1. Diagram of micellar orientation according to Nägli.
(After Frey.)

surface of green wood broken along the grain is longitudinal. The thin-walled vessels split cleanly along their longitudinal axis and the edges of the break are smooth. Forsaith explains this by assuming the break to have occurred in the water films between parallel, longitudinally oriented micellæ. The spiral structure he explains by supposing the micellæ to be of a rhombohedral shape and so arranged that the water films on the ends of the micellæ form spiral lines of weakness (Fig. 2). This structure explains equally well the unequal swelling of wood blocks and the spiral and longitudinal cleaveage planes that occur in wood cells.

Fischer (8) however, has recently pointed out that evidence from both purely physical as well as physiological sides is strongly against the existence of such water films. If two smooth glass plates are pressed together and water is allowed to rise by capillarity between them, they are not pushed apart, but drawn tightly together. Even more conclusive is the fact that alcohol, ether and chloroform which enter the cellulose wall more rapidly than water, produce absolutely no trace of

swelling.   Were swelling the result of liquid films around the micellæ, these liquids should produce it.   These facts have made necessary a modification of the original Nägeli theory. It is highly probable that the spaces between the micellæ are not empty, as Nägeli believed, but are filled with a highly hydrophilic colloid.   The general presence in cell walls of the hydrophilic colloidal phosphotides discovered by Hansteen-Cranner (loc. cit.) is of undoubted importance in this respect. Other workers have suggested other colloidal substances.   In young membranes this colloidal intermicellar substance may be of pectic nature.   In young Closterium walls one can see the
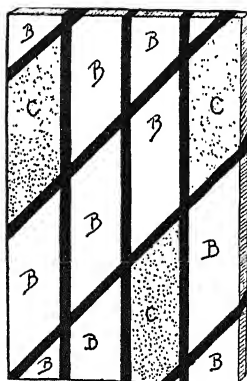
Fig. 2.   Forsaith's modification of the Nageli diagram of micellar orientation.
Solid black bands represent water films.
B, Cellulose units; C, Lignincomplex.   (After Forsaith).

double refraction of the cellulose gradually appear and increase in the isotropic membrane (10).   In cellulose walls an amorphous cellulose may form the colloidal matrix (21).   In cutinized and suberized membranes, it may be the cutin and suberin (10) and in lignified walls, the lignin.   That lignin is *between* the cellulose micellæ and not *in* them is proven by the fact that lignified walls give the X-ray pictures of pure cellulose (10).

The existence of double refraction alone is not sufficient to prove the crystalline nature of cellulose units.   Double refraction can also be produced by non-crystalline, isotropic units under certain conditions (2).   Ambronn (2) by studying the behavior of cellulose under polarized light, has been able to prove both the existence of micellæ in the cellulose walls and the crystalline character of these micellæ.

If isotropic rods, (glass, for example), whose diameter and distance from one another are small relative to the wave length of light, possess a refractive index of N_1 and are imbedded in a liquid whose refractive index is N_2, the body will appear doubly refractive.   If N_2 is varied, the double refraction varies accordingly.   When $N_1 = N_2$, there is no double refraction, but when $N_1 \gtrless N_2$ a value arises.   The curve of these variations is parabolic in form.   By saturating the plant membrane with liquids of increasing refractive index (water, alcohol, glycerine, anilin, etc), Ambronn found his curve agreed with the theoretical curve, thus proving the existence of such submicroscopic rods in the membrane.   Since he was never able

A   B   C
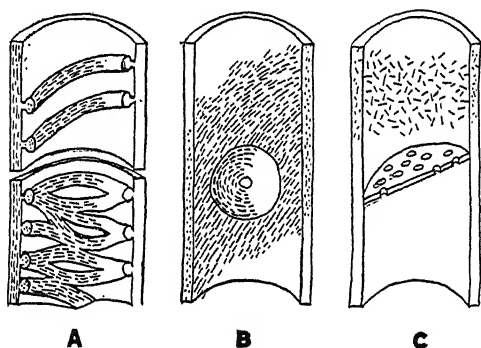
Fig. 3. The orientation of the crystalline micellæ in different cell walls.
A, Tracheæ with spiral and reticulate thickenings; B, Tracheid with bordered pit;
C, Sieve tube.   (After Frey).

to find a value of 0, i. e., his curve did not fall to the 0 point, he concluded that the rods (cellulose micellæ) were themselves doubly refractive (12).

Frey (10, 11, 12) has extended this work in brilliant fashion. He has developed a method of determining the orientation of the micellæ in the cell wall by using a polarizing microscope. Since the morphological long axis of the submicroscopic crystalline micellæ corresponds to the direction of the greatest refractive index, it is not difficult to determine the orientation of the micellæ in the wall.   It resolves itself into a matter of determining the direction of the greatest refractive index.

The long axis of these micellæ often parallels the striations visible on the wall surface.   In strong cell walls (bast fibers, etc.), the micellæ are united to form long fibrillæ, which are

usually spirally wound around the cell at steep angles.   Groups
of these fibrillæ can be seen by swelling the cell wall.   They
have recently been studied by a number of investigators,
particularly in the commercial fibers.   (Anderson (3), Ball (6),
Nodder (28), Reimers (29) and others).

Frey (12) has determined the orientation of the micellæ in a
number of different cell walls.   The micellæ exhibit a wide
variety of patterns and show no constant or definite arrange-
ment common to all cell walls.   In bast fibers they are arranged
nearly parallel to the long axis of the cell; in sieve tubes and
lactic ducts the arrangement is irregular, with no definite
orientation; in tracheæ the micellæ parallel more or less the
long axis, but in the spiral and reticulate thickenings are nearly
perpendicular to the long axis of the cell; in tracheids they are
arranged in a steep spiral except at the bordered pits, where
they are concentrically arranged around the pore opening.
(Fig. 3).

Cutinized membranes such as are usually present in
epidermal cells consist of three layers: an outer layer of cutin,
an inner layer of cellulose, and between, a layer of cutinized
cellulose.   This structure has been worked out microchemically
(34).   Studies with polarized light both confirm and extend
this conception.   Frey (11) has demonstrated that with polar-
ized light it is possible to determine accurately the location and
the degree of cutinization of such membranes.   Cutin is
optically negative, while cellulose is optically positive.   With
the insertion of a Gypsum plate Red 1 in the polarizing micro-
scope, these two membrane substances give the contrasting
addition and subtraction colors.   The cutinized portions of the
wall appear a brilliant yellow, while the adjacent cellulose
appears bright blue.   With the rotation of the stage through
90 degrees the colors are, of course, reversed.

Examination of the walls of heavily cutinized cells (epi-
dermal cell walls of Clivia nobilis and Acuba japonica) under
polarized light brings out distinctly the three layers.   The
outer layer of cutin is isotropic, probably because of the physical
arrangement of the micellæ.   The two inner layers of cutinized
cellulose and cellulose, respectively, are both anisotropic, but
the former is optically negative, while the latter is optically
positive.   The layer of cutinized cellulose shows a region of
maximum anisotropism at its center, the degree of double
refraction decreasing from the center toward the layer of pure

cutin on the outside and toward the layer of cellulose on the inner side. The cellulose layer, likewise, shows a higher degree of double refraction at its center.

The polarizer further reveals that in some cases (Acuba japonica) the layer of cutinized cellulose is not continuous, but that each epidermal cell has a separate, distinct, plate-like layer of its own. Frey has also shown that the boundaries between these three layers are sharp and distinct, there being no gradual transition from one to the other.

Ultraviolet light passes through cellulose but not through cutin, so photographs taken with ultraviolet light will show whether any cutin is present in the cellulose layer. This is not the case; the cellulose layer shows no sign of cutin even at the extreme outer edge of the layer. The boundary is sharp and definite. No study of the boundary between the cutinized cellulose layer and the outer layer of pure cutin can be made with ultraviolet light, since both appear black. This can be done, however, with polarized light, for the cutin layer is here completely isotropic, because of its physical structure, and the cutinized cellulose layer is anisotropic. Here again, the boundary between the two is sharp and definite, (10).

In this way studies of the membrane with polarized light have extended the results of microchemical investigations, as well as completely confirmed them. The use of polarized light in specific cases offers a much simpler and more precise method of learning the relations between the various cell wall lamellæ, than microchemical methods.

Pectic compounds are isotropic and can be detected in cell walls when relatively unmixed with cellulose, by the use of polarized light, (11). When pectic compounds occur associated with cellulose, the double refraction of the latter obscures the isotropic character of the former, (if the cellulose is present in appreciable amounts), and the presence of the pectic material cannot be clearly detected (4).

Hemicelluloses are at least in part doubly refractive, an indication that like pure cellulose, they are probably composed of crystalline micellæ (11).

Polarized light also gives evidence as to the relations of the lignin complex to cellulose. Lignified tissue is doubly refractive, but if the cellulose is removed, becomes completely isotropic (11). This indicates that the lignin complex is amorphous and that the anisotropic character of lignified walls is due to the

cellulose present. The removal of the lignin complex from lignified tissue does not affect in any way the degree of double refraction. The amorphous character of the lignin is also confirmed by X-ray analyses as has been mentioned previously.

In brief, polarized light offers not only a method of detecting and accurately localizing certain membrane constituents, but makes possible a determination of the orientation of the crystalline micellæ in the cellulose cell wall. It has been responsible for a great increase in our knowledge of the details, particularly the submicroscopic details, of cell wall structure. In speaking of the importance of polarized light, in relation to the evidence for the Nägeli micellar theory, Frey (10) says,

"Die hier summarisch aufgefuhrten Grunde, die für die Existenz der Micelle sprechen, und die Tatsachen die uber das Auftreten und die Eigenschaften der Intermicellarräume Auskunft geben, zeigen deutlich dass die Micellartheorie nicht mehr hypothetisch, sondern weitgehend bewiesen ist."

X-ray analyses have made possible a still further advance in solving the problems of cell wall structure. X-ray pictures of cellulose fibers give the interference patterns of crystal structure. The character of these interference diagrams indicates the arrangement of the crystalline units in the wall. Plant fibers have generally shown a crystalline fibrillar structure in which the crystals lie with their morphological long axis in approximately the fiber axis. The orientation of these fibrillæ varies in different fibers. In bast fibers of flax the fibrillæ run in a steep spiral, but the direction of the spiral alternates in successive lamellæ of the wall. In bast fibers of ramie and hemp, the fibrillæ also have a steep spiral arrangement, but the angle of the spiral varies in successive lamellæ. Cotton fibers show the same spiral structure, but here the spiral reverses its direction at points in the same lamella. The interpretations of X-ray photographs of the fibers agrees with these direct microscopical observations. Cotton, for example, gives an interference pattern that indicates a structure of spirally wound fibrillæ, while the diagram of flax fiber indicates a reversal of the fibrillar direction, (21).

Beyond confirming the presence of definite crystalline units in the cellulose wall, and indicating the arrangement of these crystals, the X-ray analyses have shown that an amorphous material is also present. To quote Herzog, (22),

"Aus den Röntgen-Bildern der Fasern ergibt sich die Anwesenheit nicht unerheblicher Mengen amorpher Stoffe— vielleicht auch amorpher Cellulose—neben den Krystallen. Man wird sie als Einbettungs—substance ansehen."

That cellulose is not a single chemical compound has also been suggested by Arrhenius (5) from studies of its reaction energy. Haller (16) came to the same conclusion from investigations on the behavior of the hydro- and oxycelluloses, derived from cotton fibers, when treated with NaOH.

This amorphous substance surrounding the crystalline units acts as an insulating material by preventing the crystalline micellæ from coming into direct contact with each other. Were no such substance present, the continuous stresses produced in the cell wall by such external forces as winds, would bring about a recrystallization, comparable to that occurring in steel under continuous hammering. Such a recrystallization would greatly reduce the resistance of the cell wall to such stresses. The presence of this amorphous, intermicellar, insulatory, colloid prevents this from taking place (21).

Herzog (21) suggests an interesting theory to account for the orientation of the crystalline micellæ in plant fibers. The first wall formed by the cell is amorphous (pectic material). In this amorphous substance the cellulose mother substance is assumed to be present as small droplets. These droplets rapidly crystallize. Since, however, they are under stresses brought about by the growth of the cell wall, they crystallize in definite directions. The long axis of the crystal conforms to the direction of the stresses, i. e., they are arranged more or less parallel to the long axis of the cell. The degree of tension determines the degree of crystallization. Such crystallization occurs in the manufacture of artificial fibers from cellulose solutions, and it is entirely possible that a similar crystallization takes place in the formation of the cell walls of fiber cells.

This cannot be the only factor involved, however, for the direction of these crystalline fibrillæ is not constant in all fibers, (flax, hemp, ramie, etc.). Such a theory could hardly account for the reversal of the direction of the spiral in bast fibers of flax, for example. It is possible that cellulose crystals in this case are isomeric, and that the alternate left and right hand spirals is the result of an alternation of isomeric celluloses (3).

The theory of Herzog also runs into difficulties when the case of sieve tubes and lactic ducts is considered. In these cell

walls, as Frey (12) has shown, the micellæ are irregularly distributed with no definite arrangement. These walls must also have been subject to the stresses of cell wall growth, yet here these forces have apparently produced no definite micellar orientation.

X-ray studies of cellulose walls confirm both the results of microchemical work, and the results of polarized light investigations. These three methods of study have established the crystalline micellar theory of cell wall structure upon an impregnable basis.

SUMMARY.

In the light of modern research, all cellulose cell walls, as well as those containing cellulose in considerable amounts, possess a submicroscopic structure of crystalline micellæ. These micellæ are imbedded in an amorphous matrix, the chemical nature of which varies in different walls and probably at different stages in the development of the same wall. The orientation of the crystalline micellæ is not constant in all walls, but varies widely.

From the standpoint of microscopic structure, the wall is a complex of several chemically different lamellæ. The lamellæ may consist of but one chemical substance, and alternate with lamellæ of other cell wall constituents, or the various constituents may be present in the same lamella.

This complex structure is saturated with colloidal phosphatides, that are in intimate union with the outer protoplasmic layers. These colloidal phosphatides are unstable and are readily modified by varying conditions. The physiological significance of their presence in the wall is not at the present time completely understood.

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SPERMATOGENESIS IN BRANCHIPUS VERNALIS.

PART III.

SECONDARY SPERMATOCYTE, SPERMATID AND SPERMATOZOÖN.

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In two previous papers, Baker and Rosof, Part I, 1927 and Part II, 1928, the general description of the testis and the behavior of the chromatin of the spermatogonia and primary spermatocyte in Branchipus vernalis was described. The outstanding features of the behavior of the chromatin in the spermatogonia are as follows: (1) There are twenty-three chromosomes in the spermatogonia of Branchipus vernalis: (2) There are eleven pairs of homologous chromosomes and one accessory; (3) In the late prophase stage of the spermatogonia, some homologous chromosomes are paired. This pairing was interpreted as being more of a chance occurrence than a regular behavior in the activity of the chromosomes.

The following summary briefly states the changes occurring in the chromatin of the primary spermatocyte:

(1.) The early primary spermatocyte is characterized by a reticulum in which the arrangements of the chromatin is in the form of masses and strands. There is a difference in the number, size, form and relationship of these chromatin aggregates and strands. Some of the chromatin bodies found in different nuclei show marked similarities. The reticulum characteristic of this early stage is affected by the separation of chromosomes from the dense mass of the telophase plate of the last spermatogonial division. This is the early prochromosomal stage;

(2.) The reticulum becomes less pronounced and the chromatin bodies reveal characteristic shapes. The number of chromatin masses is not constant in the various nuclei but in no case does the number of masses exceed twenty-three. This is the late prochromosomal stage;

(3.) The recticulum is less pronounced. In the previous stage, the chromatin aggregates were the more conspicuous elements in the nucleus, whereas, in this stage the strands are

more pronounced.   Some of the strands resemble the elongate and ill-defined chromosomes.   This characterizes the unraveling stage.   These three stages compose the preleptotene stage;

(4.)   The chromosomes now undergo a series of changes involving the following processes: (a) Synapsis of homologous chromosomes; (b) Orientation of unlike chromosomes into an end to end association; (c) Equalization in thickness and change in form of chromosomes into definite, uniform and elongate chromosomes.   The simultaneous manifestation of these three processes is interfered with by the differences in the relationship of the chromosomes as they emerge from the last spermatogonial telophase.   This constitutes the leptotene stage;

(5.)   The chromosomes for the most part are well defined bivalent loops which are associated end to end, and are peripherally arranged in respect to the nucleus.   This marks the close of the processes which are operating in the pre-leptotene and leptotene stages and marks the initiation of the processes which are involved in the post-leptotene stage.   This is the transitional stage.

The post-leptotene stages following the transitional are summarized as follows:

(6.)   The chromosomes may or may not form bouquets prior to the following pachytene stage.   These two methods of chromosomal transformations may be interrupted by the intervention of synizesis;

(7.)   The chromosomes shorten and assume characteristic forms.   These chromosomes are scattered throughout the nucleus.   This is the pachytene stage;

(8.)   The chromosomes elongate and thicken and simulate an ill defined bouquet.   Some of the chromosomes are partially coalesced and are less distinct.   This constitutes the second orientation;

(9.)   Chromosomes become more diffuse and separate, but at the same time the individual chromosomes are again undergoing a process of shortening.   This corresponds to the diffuse stage;

(10.)   Chromosomes are shortened and contracted and are so intermingled that they somewhat simulate synizesis.   This is the second contraction;

(11.)   Chromosomes now are no longer diffuse but are separated and again assume characteristic shapes.   This is the diakinesis stage;

(12.)   The chromosomes become still further contracted and rounded.   At this time some of the chromosomes are joined to each other.   The nuclear membrane disappears.   This constitutes the late prophase stage in contrast with all previous stages which are parts of the early prophase.

(13.)   Metaphase follows and meiotic division ensues.

In regard to the question of synapse it is inferred that the interval and mode of synapse is dependent upon the arrangement of chromosomes as they emerge from the last spermatongonial division and to the sequence of the processes as indicated in the leptotene stage.   The chromosomes of this species do not synapse in the same condition nor do they synapse at the same time.   If the chromosomes synapse while in the form of filaments, then the mode of synapse is unquestionably parasynaptic.   On the other hand, if synapse occurs during the clumped condition of chromatin, it is impossible to determine with certainity whether or not the mode of conjugation is parasynaptic or telosynaptic.

The present paper is limited chiefly to the description of the observations covering the behavior of chromosomes of the secondary spermatocyte, spermatid and spermatozoön.

THE SECONDARY SPERMATOCYTE.

The secondary spermatocytes are arranged in the testis in cysts as were the spermatocytes of the first order.   In transverse section of the testis the cysts are well defined and are distinctly localized toward or near the immediate vicinity of the lumen of the gland.   The cells composing these cysts are comparable to the cells of the first order only in their shape which is round or oval unless encroached upon by surrounding cells and under such conditions a variety of cell contours may result.   The secondary spermatocytes are somewhat smaller than the primary spermatocytes.

Following the primary spermatocyte division, the nucleus of the secondary spermatocyte reveals the chromatin disposed in a darkly staining and clumped mass in which the individuality of the chromosomes are more or less obscured.   This condition is shown in Figure 1.

The ensuing changes that the chromosomes of the secondary spermatocyte undergo are unlike the changes which occur in the early prophase of the primary spermatocyte.   The behavior

of the chromosomes of the secondary spermatocyte is uncomplicated in that no factors are involved excepting those which operate in connection with mitotic divisions.

Figures 2 and 3 show the chromosomes less intimately related. The individual chromosomes can now be distinguished by their differences mainly in size, and to a lesser extent by differences in their morphological aspects. Some of the chromosomes show connecting strands which are similar to those which connect metaphase chromosomes of the primary spermatocyte. This feature is more pronounced in Figure 2 than in Figure 3. These two figures contain eleven chromosomes each.

Further changes result in the elongation and change in form of the chromosomes so that each chromosome is morphologically dissimilar to the others, and at the same time the connecting strands are less pronounced and for the most part disappear. The chromosomes now are more or less uniformly distributed throughout the nucleus and are somewhat peripherally arranged in relation to the nuclear membrane, (Figure 4.). The full count of chromosomes is not present in Figure 4 since only ten are visible. The chromosomes in Figure 5 are in a later stage and the chromosomes are more elongate. In the lower portion of the nucleus, two strands connecting chromosomes are seen. Some of these nuclei have their central portions somewhat constricted. This cell gives a count of twelve chromosomes.

The next change reveals the chromosomes undergoing contraction. The individuality of the chromosomes at this stage is most pronounced and they ·exhibit in the main well defined and characteristic contours. It may be emphasized that the chromosomes of this stage are comparable to the spermatogonial chromosomes of a similar stage. Strands connecting chromosomes are no longer visible, (Figures 6, 7 and 8). Figures 6 and 7 show eleven chromosomes while Figure 8 has twelve.

Figures 9, 10 and 11 are polar views of metaphase. These chromosomes are in the form of rounded bodies which may be distinguished from each other by differences in size. Figure 9 shows a central mass of chromosomes which are closely approximated from which extend spindle fibers. There are five chromosomes in the immediate vicinity of this central mass which are apparently lagging behind. No nuclear membrane is present in this or in the succeeding figures of the secondary spermatocyte.

Twelve chromosomes are seen in Figure 10. The arrangement of the chromosomes as seen in this figure is quite character-

istic of secondary spermatocytes of this stage. Figure 11 shows a mass of chromosomes with one chromosome free. It is inferred that this is the accessory chromosome.

Figures 12 to 14 are profile views of early metaphase. The chromosomes of Figure 12 show a slight irregularity in their behavior in that three chromosomes are proceeding to their respective poles in advance of the remaining chromosomes.

Figure 13 shows a dense metaphase plate which is so orientated that it reveals an oblique view. The accessory chromosome is present and is proceeding precociously and undivided to one pole. Figure 14 presents a similar view, however, the accessory chromosome is divided and occupies the poles of the spindle.

Figure 15 is an anaphase while Figure 16 and 17 are telophases. The latter figure is of interest in that it shows the beginning of a nuclear membrane. The contained chromosomes do not show the massed condition which is more in evidence in the previous stages.

THE SPERMATID AND SPERMATOZOÖN.

The spermatids are located around or near the lumen of the testis in a cyst-like arrangement being present throughout the entire extent of the testis but far more numerous in the anterior extremity of the gland. The arrangement in the cysts is not as typical as was the condition in the preceding stages and the contour of the cyst is not so well defined and is frequently absent. Spermatids may be found also in the lumen of the testis intermingled with the spermatozoa.

In shape, the spermatids vary from a round or oval to an oblong form and are distinctly smaller in size than the spermatocytes of the second order.

Figure 17 shows a late telophase stage of the secondary spermatocyte and reveals the characteristic massing of the chromosomes. In some cells this packed condition partially obscures the individual chromosomes, but usually the chromosomes can be distinguished. Eleven chromosomes are seen in Figure 18. These chromosomes are rounded and somewhat massed. Strands connecting chromosomes are visible. There is little difference in shape of individual chromosomes but a difference in size is more pronounced and with careful scrutiny the individuality of the chromosomes can be detected. The

area occupied by the chromosomes is marked off from the cytoplasm by a nuclear membrane. On the left, in the immediate proximity of the nuclear membrane are two well defined centrosomes. This condition of divided centrosomes is common in spermatids and spermatozoa. The cytoplasm in this figure as well as in the succeeding figures is not shown. This is the typical condition of the nucleus of a spermatid following the secondary spermatocyte division.

Following the rounded condition of the chromosomes, they assume a more elongate form with characteristic shapes. The strands connecting the chromosomes are more evident, some being more conspicuous than others. Figure 19 shows the chromosomes for the most part in a rounded condition. In the more central portion of this nucleus, an elongate chromosome is seen from which several strands extend to neighboring chromosomes. There are twelve chromosomes in this nucleus.

The chromosomes in Figure 20 show a more pronounced change in form than does the previous figure. A few connecting strands are present and some of the chromosomes are enlarged. Some of these chromosomes appear to be joining with other chromosomes. Although the full number of chromosomes is present in this nucleus a count of only ten chromosomes is obtained.

The condition of the chromosomes in figures previously described indicates the initiation of the changes which results in the final configuration of the spermatozoa. These changes involve the rearrangement and coalescence of chromosomes and results in an apparent diminution of the number of chromosomes in the spermatozoa. Figures 21 to 29 inclusive show the configuration which the chromosomes undergo in the early stages of this coalescence of unlike chromosomes.

It is difficult to obtain an accurate count of chromosomes in Figure 21 on account of the coalescence of some of the chromosomes. However, nine distinct bodies are visible. For the most part, the chromosomes reveal slight differences in shape which is indicative of the fact that the chromosomes have a tendency to change their form, but this change is not so pronounced in most cases as to obscure the recognition of the individual chromosomes. In some cases even though the chromosomes are partially coalesced certain features still remain which assure the identification of the chromosomes

entering into the coalescence. This figure also shows two well defined centrosomes.

Figure 22 shows eight bodies of chromatin six of which are well defined. The two chromosomes in the central part of the nucleus are partially coalesced. Strands connecting chromosomes are evident. Some of the chromatin bodies of this nucleus resemble the chromosomes of previous stages in the spermatogonia, primary and secondary spermatocytes, as well as, chromatin bodies in other spermatids. Eight well defined chromatin bodies, some of which are joined by connecting strands are seen in Figure 23. One centrosome is shown in this figure. Six chromatin bodies, five of which are well rounded and peripherally arranged are seen in Figure 24. The more central, larger, elongate and irregularly shaped chromatin body which is connected to three of the peripherally arranged chromatin bodies by single thin strands is the result of the coalescence of several chromosomes. This cell shows one large centrosome.

Figure 25 shows several chromosomes coalescing at the same time, there being only two chromatin bodies which are free. This condition is slightly different from the nucleus just described in that the chromosomes are so orientated as to permit a more rapid union than is indicated in the previous figures. It will be noted that the connecting strands are heavy and that the chromosomes joined by these strands are in close proximity to each other. One centrosome is present.

Figure 26 shows seven chromatin bodies whose appearance is similar to Figures 22 to 24. Two centrosomes are seen in Figure 26. Figure 27 contains seven bodies of chromatin. This figure is different from the preceding ones in that the strands are more numerous.

Figure 28 shows in a pronounced manner the coalescence of chromosomes. One chromatin body is free. Three well defined and rounded chromatin bodies are seen in Figure 29, as well as two large irregularly shaped masses of chromatin. The nuclear membrane is indistinct.

It is evident in the previously described Figures 18 to 29 inclusive that the following processes are involved in the behavior of chromatin: (1) Change in form; (2) Rearrangement; (3) Coalescence. These three processes operate simultaneously, and continue until the final configuration of the chromatin in the spermatozoa is reached. The changes in the morphology

of individual chromosomes do not affect all chromosomes equally and as a result the same chromosomes may be subject to a variation of contour. Nevertheless, with careful of servation individual chromosomes can be recognized regardless of the variation that they undergo in the various nuclei even though they have changed in contour they retain sufficient characteristics of size and shape to be distinguished.

The rearrangement of chromosomes is indicated by change in relation that individual chromosomes assume to each other and this relation becomes more conspicuous in the ensuing figures. Furthermore, the picture which results from the rearrangement of the chromosomes of any stage indicates that there are several distinct methods involved in the rearrangement of chromosomes prior to the final configuration in the spermatozoön bodies. The same chromosomes may form a different pattern in different nuclei in the same stage depending upon the various relationships assumed by these chromosomes.

The coalescence of chromosomes is revealed by the apparent reduction in the number of chromosomes without an apparent diminution of chromatin content as the spermatids differentiate. During this process of change in the spermatid there is shown a fusion of chromosomes. The rapidity with which chromosomes fuse is for the most part dependent upon the conditions of the chromosomes, and, as well the orientation of the chromosomes. In the early part of this process when only a few of the chromosomes are coalesced, the chromosomes which enter into this fusion retain sufficient characteristics to make them recognizable and furthermore with careful observation the exact method of fusion of chromosomes can be determined.

Figure 30 shows seven masses of chromatin six of which are partially coalesced. Their arrangement is in the form of an incomplete circle and the individual contours of each mass is discernible. The nuclear membrane is absent.

There are six rounded and well defined chromatin bodies in Figure 31. Their disposition is similar to that shown in the preceding figure but they do not show the degree of coalescence that is indicated in the previous figure. Strands are visible which connect the chromosomes, some of which are heavier than others.

Figures 32 and 33 are similar in that each figure presents five chromatin bodies which are connected to each other by varying sized strands. The arrangement of these chromatin

bodies simulates a quadrangular form, the angles of which are occupied by a chromatin body. The other chromatin body partially obscures this configuration. Figure 33 shows the entire spermatid.

Figures 34 to 40 inclusive show the same number and similar orientation of chromatin bodies. The arrangement of the chromatin in these cells simulates an irregular quadrangle with a chromatin body at each angle. These bodies are connected by communicating strands which form the sides of the figure. The patterns presented by these chromatin bodies differ from each other in the following respects: (1) difference in size and form of the chromatin bodies; (2) difference in the length and degree in attenuation of the connecting strands. An additional strand is present in Figure 34 which connects two chromatin bodies. No accessory chromosome is present in Figures 35 to 40.

These figures just described suggest the manner in which the final spermatozoön configurations of chromatin bodies may be achieved. It may be inferred that the connecting strands which are thin and attenuated will disappear while the heavier one will persist and the smaller chromatin bodies will coalesce with the larger bodies. This inference is supported by the succeeding figures.

Figures 41 to 43 show four chromatin bodies which are similar to the figures just described but differ to the extent that the reduction in the number of connecting strands is evident. No accessory chromosome is present. Figure 42 shows the entire cell.

Since the change from a spermatid to a spermatozoön involves a process of metamorphosis, it is impossible to tell just where a line demarcating the differentiation should be drawn. However, the following may be used as a criteria for the identification of a spermatozoön: (1) The cells that contain two or three bodies of chromatin completely or incompletely connected by strands. No accessory chromosome present, (Figures 45 to 62); (2) The cells that contain four bodies of chromatin incompletely connected by strands. No accessory chromosome present, (Figures 41 to 43). The accessory chromosome when present constitutes an additional body in the above mentioned spermatozoa and it can be distinguished by its isolation and shape, (Figures 63 to 71).

Figures 44 to 52 are spermatozoa containing three chromatin bodies. No accessory chromosome is present. Figures 44 and

45 differ from the other figures to the extent that the chromatin bodies are completely connected by strands. One additional strand is present in Figure 44. A complete cell is shown in Figure 44. Figures 46 to 48 are similar stages showing heavy strands which partially obscure the identity of the chromatin masses. Figures 49 to 51 show a similar pattern of chromatin. The chromatin bodies are approximately the same size and shape and the more peripherally placed bodies are connected to the central bodies by a u-shaped strand, Figure 52.

Figures 53 to 62 show the final configuration of the chromatin in the spermatozoa. No accessory chromosome is present in any of these figures. In all these figures there are only two bodies of chromatin. In Figure 53 the bodies are approximately of the same size and the connecting strand is short and thick. Extending from one mass there is a thick extension of chromatin. Figure 54 shows two bodies of chromatin, one being V-shaped and the other elongate. These two chromatin bodies are practically united without the intervention of a connecting strand. The chromatin in Figure 55 is in the form of a crescent. Figures 56 to 58 reveal approximately equally sized masses of chromatin connected by strands which show differences in length, thickness and disposition. Figures 59 and 60 show an elongate mass of chromatin connected by strands to smaller rounded bodies of chromatin. Two unequal sized bodies of chromatin are seen in Figures 61 and 62. In Figure 61, the bodies are connected by a very thin and long strand while the chromatin bodies of Figure 62 are separate. The smaller body of this figure shows an irregular strand extending from it. This figure also shows two well defined centrosomes.

It must not be inferred that the arrangement of the chromosomes in the chromatin bodies is the same in every spermatozoön, as has been previously stated there are several methods by which these various configurations may be produced. The spermatozoa thus far described contain no accessory chromosome.

Figures 63 to 71 are stages of spermatozoa which show, in addition to the ordinary chromatin bodies, an accessory chromosome. Approximately one half of the spermatozoa show the presence of the accessory chromosome. Four masses of chromatin and in addition the accessory chromosome are shown in Figure 63. Figure 64 shows three bodies of chromatin circularly disposed and in addition the accessory chromosome. Three well defined rounded bodies of chromatin which are con-

nected to each other are seen in Figure 65. The accessory chromosome is seen to one side. Figures 66 to 71 show the final chromosomal configuration of spermatozoa that contain the accessory chromosome and it is separate from the main mass of chromatin. By reference to previous figures of mature spermatozoa, (Figures 53 to 62), it is seen that the configuration of the chromatin corresponds in these figures to a similar configuration containing the accessory chromosome, (Figures 66 to 71).

In making a survey of the cysts which contain spermatozoa, it is seen that approximately one half of the contained cells show the distribution of chromatin as indicated by Figures 66 to 71. The shape of the accessory chromosome is quite constant and invariably is isolated from the ordinary mass or masses of chromatin. Approximately, the other one half of the spermatozoa do not reveal an accessory chromosome, (Figures 53 to 62). For this reason, it seems justifiable, therefore, to conclude that in the spermatozoa of Branchipus vernalis sexual dimorphism is clearly demonstrable.

CONCLUSIONS.

1. The secondary spermatocytes are of two types: first, those with eleven autosomes and, second, those with eleven autosomes and one accessory chromosome.

2. The accessory chromosome may divide or proceed undivided to one pole of the cell in the secondary spermatocyte division. In either case the accessory chromosome precedes the autosomes.

3. In the spermatids and spermatozoa the chromosomes undergo a series of changes involving the following processes: (1) change in form of the chromosomes, (2) the rearrangement of the chromosomes, (3) coalescence of chromosomes. These three processes operate simultaneously and continue until the final configuration of the chromatin bodies in the spermatozoa is attained.

4. The arrangement of the chromosomes in the chromatin bodies of the spermatozoa is not the same in every case.

5. The centrosome may or may not be divided in the spermatozoa.

6. Sexual dimorphism is demonstrable in the spermatozoa since approximately one half of the spermatozoa contain the accessory chromosome.

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EXPLANATION OF PLATE I.

(All figures were drawn by aid of the camera lucida at a magnification of 1250 diameters).

Fig. 1.   A secondary spermatocyte immediately following the primary spermatocyte division. The chromatin is disposed in a darkly staining mass.

Figs. 2 and 3 are early prophase stages of the secondary spermatocyte showing definite and rounded chromosomes. Each cell contains eleven chromosomes, some of which are connected by intervening strands.

Fig. 4.   The beginning of a change in form of the chromosomes is seen in this figure. The connecting strands are less pronounced. This cell does not contain the full complement of chromosomes.

Fig. 5 shows a later prophase stage characterized by the elongation of the chromosomes. Twelve chromosomes are present in this nucleus.

Figs. 6, 7 and 8 show the chromosomes undergoing contraction. These chromosomes are well defined and exhibit characteristic contours. The nuclei in Figures 6 and 7 contain eleven chromosomes, while Figure 8 has twelve.

Figs. 9, 10 and 11 are polar views of metaphase. The nuclear membrane is absent. In Figure 10, twelve chromosomes are seen. Figure 11 shows one free chromosome at the side of the main mass of closely clumped chromosomes and is interpreted as being the accessory.

Fig. 12.   A profile view of an early metaphase.

Fig. 13.   A profile view of an early metaphase plate oriented obliquely. The accessory chromosome is seen toward the upper pole.

Fig. 14.   A profile view of a metaphase similar to the preceding figure. The accessory chromosome is divided and occupies the poles of the spindle.

Fig. 15.   Anaphase.

Fig. 16.   Telophase. In the lower portion of the figure, eleven chromosomes are seen.

Fig. 17.   Telophase. Individual chromosomes are evident. Note the beginning of a nuclear membrane.
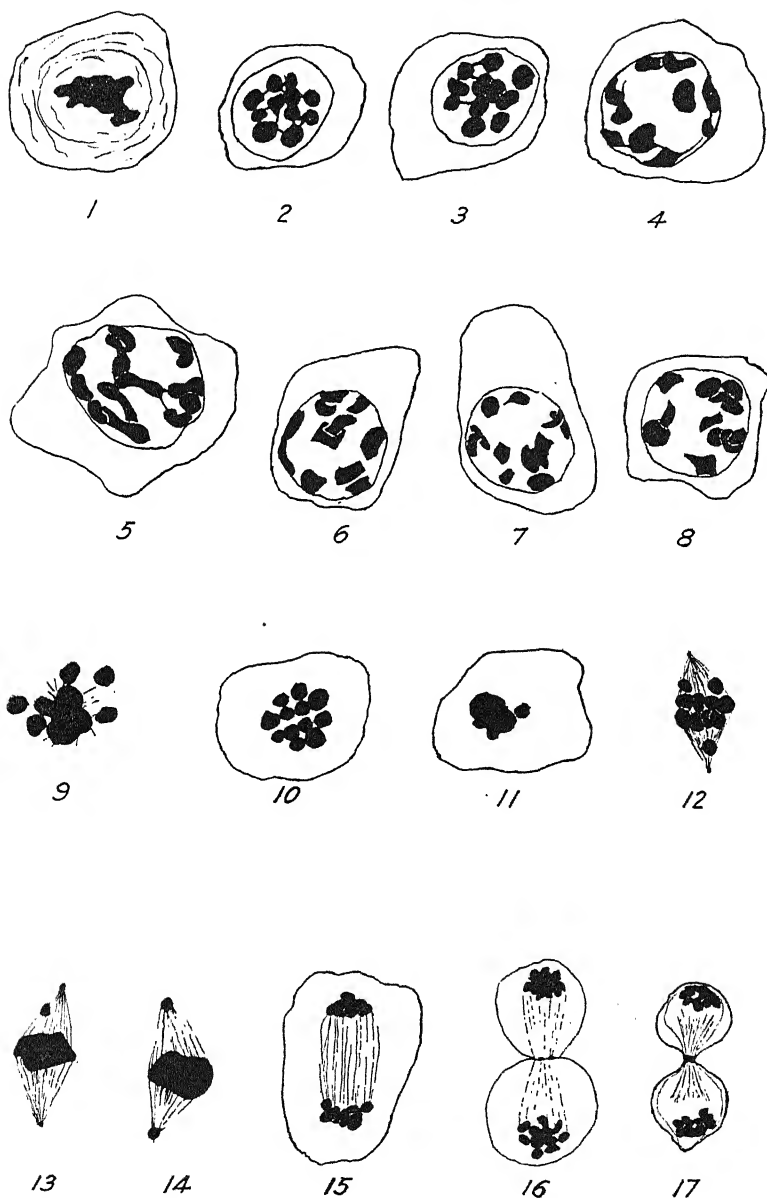
PLATE I.

EXPLANATION OF PLATE II.

Fig. 18. An early spermatid showing eleven rounded chromosomes. Strands connecting some of the chromosomes are visible. To the left near the nuclear membrane two centrosomes are present.

Fig. 19. This spermatid nucleus contains twelve chromosomes, the majority of which present a rounded contour. The connecting strands are more pronounced.

Fig. 20. A change in form of the chromosomes is evident. Note the apparent joining of chromosomes, and decrease in number, although the full complement of chromosomes is present only a count of ten is obtained.

Figs. 21 to 29 show the configurations which the chromosomes undergo in the early stages of coalescence of unlike chromosomes. It is impossible to make an accurate count of chromosomes in Figure 21, however, nine distinct chromosomes are visible. Two centrosomes are present.

Figs. 22 shows eight bodies of chromatin, six of which are well defined. In the central part of the nucleus two chromosomes are partially coalesced. Strands connecting the chromosomes are pronounced.

Fig. 23. Eight well defined chromatin bodies, some of which are joined by strands, are seen in this nucleus. One centrosome which lies close to the nuclear membrane is visible.

Fig. 24 contains six chromatin bodies. Five of these bodies are round and are peripherally placed. Note the more central, large and irregularly shaped chromatin body which was formed by the coalescence of several chromosomes. One large centrosome is present. .

Fig. 25 shows the simultaneous coalesence of several chromosomes. Only two chromatin bodies are free. One centrosome is visible.

Fig. 26. Seven chromatin bodies are seen in this nucleus and also two centrosomes.

Fig. 27 contains seven bodies of chromatin. The connecting strands are more numerous than in the preceding figures.

Fig. 28 shows distinctly the coalescence of the chromosomes. One chromatin body is free.

Fig. 29. This nucleus shows five large chromatin masses, three of which are rounded. The nuclear membrane is becoming less distinct.

Fig. 30 shows seven masses of chromatin, six of which are partially coalesced, arranged in the form of an incomplete circle.

Fig. 31. Six definite rounded chromatin masses are seen in this nucleus. The degree of coalescence is not so marked. The connecting strands are quite conspicuous.

Figs. 32 and 33 are similar in form. Each of these nuclei present five chromatin bodies connected to each other by varying sized strands. The entire spermatid is shown in Figure 33.

Figs 34 to 40 inclusive. These nuclei show the same number and similar disposition of the chromatin whose arrangement simulates an ill-shaped quadrangle with a chromatin body at each angle. An additional connecting strand is seen in Figure 34. No accessory chromosome is present in these nuclei.

Figs. 41 and 42 show four chromatin bodies, the disposition of which is similar to the preceding figures. A reduction in the number of connecting strands is seen. The accessory chromosome is absent. The entire cell is shown in Figure 42.

Spermatogenesis in Branchipus Vernalis. Part III.
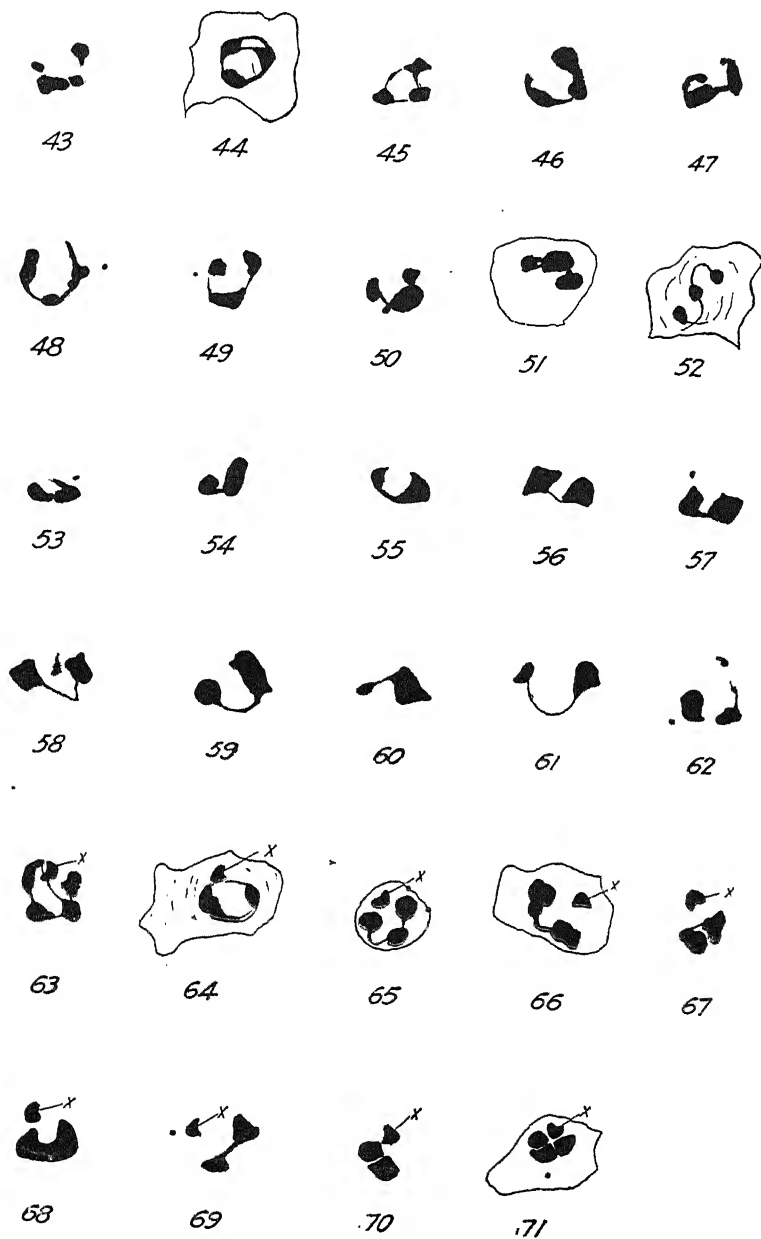R. C. Baker and J. A. Rosof.

PLATE II.

EXPLANATION OF PLATE III.

Fig. 43.   A spermatozoön containing four chromatin masses.   In this stage the accessory chromosome may constitute a fifth body.   See Figure 63.

Figs. 44 and 45 are spermatozoa containing three chromatin bodies completely connected by strands.   Figure 44 which is a complete cell shows one additional strand.   The accessory chromosome is absent.

Figs. 46, 47 and 48 are similar stages of spermatozoa.   Heavy strands are visible which connect and partially obscure some of the chromatin masses.   The accessory chromosome is absent.

Figs. 49, 50 and 51 are similar in the respect to the number and distribution of the chromatin bodies.   Figure 51 is the entire cell.

Fig. 52.   The entire cell is shown containing three chromatin bodies of nearly equal size and similar shape connected by U-shaped strands.

Figs. 53 to 62 inclusive show the final configuration of the chromatin in the spermatozoa.   Two chromatin bodies are present in these figures and are connected by heavy strands with the exception of Figure 62.   This figure contains two centrosomes.   The chromatin bodies in Figures 53 and 54 are almost united.   The accessory chromosome is absent.

Figs. 63 to 71 are stages of the spermatozoa and show in addition to the ordinary masses of chromatin an accessory chromosome.

Fig. 63 shows four masses of chromatin and an accessory chromosome.   The accessory chromosome in the following figures is marked X.

Fig. 64.   The entire cell is represented.   The chromatin bodies are circularly arranged.   The accessory chromosome is seen in the upper part of the figure and is free from the main masses.

Fig. 65.   Three rounded chromatin masses are present and are connected to each other.   The accessory chromosome is completely isolated.

Figs. 66 to 71 show the final stages of the spermatozoa that contain the accessory chromosomes.

Fig. 66 shows the entire spermatozoön.   Two large, irregular and connected chromatin masses are present.   The accessory chromosome occupies a position to the right.

Fig. 67.   The ordinary chromatin masses are connected by thin strands.   The accessory chromosome is seen in the upper part of the figure.

Fig. 68.   The accessory chromosome occupies a position above the main mass of chromatin.

Fig. 69.   The two ordinary masses of chromatin are connected.   The accessory chromosome is seen to the left near a centrosome.

Figs. 70 and 71.   The former figure shows two main masses of chromatin with the accessory above and to the right.   The latter figure reveals the shape of the entire spermatzoön.   The three ordinary chromatin masses are closely approximated, the accessory chromosome occupies an upper position with its convexity pointing downward.

CONTENTS OF VOLUME XXVIII.